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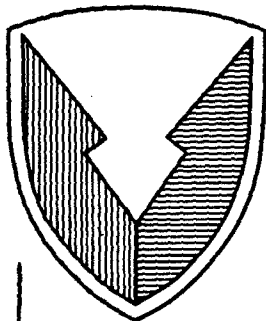
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C E N T E R

Technical Report



No. 13464

USER'S MANUAL FOR THE

RIDE MOTION SIMULATOR

AUGUST 1989

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PREFACE

This report explains how to operate the Ride Motion Simulator located at the United States Army Tank-Automotive Command (TACOM) in Warren, Michigan. It also provides a description of the facility. If there are any questions or suggestions for improvement, please feel free to contact the author at this address: Commander, U.S. Army Tank-Automotive Command, ATTN: AMSTA-RYA (Alexander A. Reid), Warren MI 48397-5000.

Guidelines on how to request use of the Ride Motion Simulator can be obtained by contacting the author.

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1.0. INTRODUCTION

This document provides a detailed analysis of and operation procedures for the Ride Motion Simulator (RMS) located at the U.S. Army Tank-Automotive Command in Warren, Michigan. The comprehensiveness of this document will also allow it to be used as the primary guide for the use and maintenance of the RMS.

This report contains the following information:

- ° A physical description of the simulator with emphasis upon the safety features.

- ° A description of system operation including safety procedures.

2.0. OBJECTIVE

The objective of this report is to satisfy the need for an operator's manual for the RMS and to provide a thorough description of its capabilities.

3.0. CONCLUSION

The RMS is a four-degree-of-freedom simulator capable of recreating the ride of any army vehicle. This manual is a user's guide for the RMS.

4.0. RECOMMENDATIONS

This report is to be used as the operator's manual for as well as to provide guidelines on the use of the RMS. As changes in the RMS warrant, this manual will be updated.

5.0. DISCUSSION

5.1. Description of the Ride Motion Simulator

5.1.1. Purpose and Intended Use of System. The RMS is fundamentally a platform mounted in a framework so that four motions (four degrees of freedom) can be imparted to it simultaneously: linear motion along the vertical axis; rotational motion about the vertical axis (yaw); rotational motion about the transverse axis (pitch); and rotational motion about the longitudinal axis (roll). The motions are generally oscillatory in nature and comparable to the motions that might be experienced in the crew compartment of a wheeled or tracked vehicle under mild to severe operating conditions. The platform is large enough to allow simulation of a crew station,

or to simply evaluate a seating configuration. Investigations can be conducted on human tolerance to vibrations in general, or task performance in a vibrational environment.

In the current configuration, the input signals are generated from computer data files created on a CRAY-2 supercomputer using computer simulation of an army vehicle operating over specific bump courses, e.g. APG, Ft. Knox. These files are then modified and used to drive the RMS using a micro-VAX II computer. With this configuration, a wide range of vehicles, bump courses, and seatings (gunners, commanders, drivers) can easily be simulated and recreated on the RMS.

5.1.2. Subsystem and Assemblies. The RMS is described under the following equipment categories (see Figures 5-1 through 5-9):

- Computer Automated Measurement and Control (CAMAC) Computer System.

- Electronic conditioning modules.
- Pneumatic control panel.
- Motion system.
- Hydraulic control panel.

5.1.2.1. CAMAC computer system. The CAMAC system acts as an interface between a micro-VAX II computer and the RMS. The micro-VAX II, which powers and controls the CAMAC, has 5M random access memory, a 71M hard disk drive, and a 95M tape drive.

Data files, which are stored on the micro-VAX II, determine the terrain profile, vehicle, and speed the RMS will simulate. These data files are output to the RMS through the CAMAC via a Digital to Analog Converter (DAC). This DAC converts digital values in a computer to voltages which are sent to the electronic conditioning modules.

The CAMAC also has the ability to sample data (analog to digital converter), sense when a switch is thrown, and determine the presence of an applied voltage (this is used as part of the safety system, described later).

5.1.2.2. Electronic conditioning modules. These modules (see Appendix E), receive the voltages from the CAMAC system, and determine if the voltages exceed a preset limit (which corresponds to a position of the RMS), condition the voltages and then send them on to the electrohydraulic servo-valves, which, in turn, power the RMS.

If an input voltage exceeds a preset limit in any of the four degrees of travel, that degree of travel will shut down and the RMS will slowly ramp down to its neutral position. If any of the roll, pitch, or yaw limits are violated, all three degrees of travel will shut down.

There are essentially only 2 10-turn potentiometers (pots.) which will need to be adjusted to operate the RMS. The SPAN pot. attenuates the input signal anywhere from 0% to 100% of its value. The STATIC pot. controls the static position of the RMS. The vertical STATIC pot. ranges in value from 0.0 to 10.0 with 4.57 being the center position. The roll, pitch, and yaw static pots. range in value from -10.0 to +10.0, with 0.0 being the neutral position. If, for some reason, the RMS shuts down to its neutral position, the vertical STATIC pot. would be turned to 1.13 (lowering the RMS to the bottom), so that the occupant could get out.

To initiate a simulation, the cycle start button must be depressed. This will increase the magnitude of the voltage to the servo-valves from 0% of the input signal to 100% of the input signal over a time span of approximately 5 seconds.

To discontinue a simulation, the cycle stop button must be depressed. This acts the opposite of the cycle start button and decreases the magnitude of the voltage to the servo-valves from 100% of the input signal to 0% over 5 seconds.

5.1.2.3. Pneumatic control panel. The pneumatic control panel (Figures 5-4 and 5-6) provides the RMS operator access to the status and control of the pneumatic safety system.

- ° Master Stop - Depression of this push button will instantly stop the RMS from travel in all four degrees of freedom.

- ° Stop Roll, Pitch, Yaw - Depression of this push button will instantly stop the RMS from travel in the roll, pitch, and yaw degrees of motion.

- ° Stop Yaw - Toggling this switch to the up/down position will stop travel in the yaw degree of motion.

- ° Stop Roll & Pitch - Toggling this switch to the up/down position will stop travel in the roll and pitch degrees of motion.

- ° Mode Select - Putting this switch in the "UP" position activates two pneumatic safety switches which are mounted near the RMS occupant. To stop motion in the RMS, the occupant needs only to press one of these switches. Putting the mode select switch in the "DOWN" position activates a dead man's switch which is held by the occupant and depressed at all

times. Release of this switch will stop all motion in the RMS.

- ° Test Vertical Valve - Depressing this switch overrides the vertical pneumatic shutoffs.

- ° High Limit Override - Depression of this switch will override the high-limit pneumatic switch on the vertical degree of motion, thereby restoring control of motion to the RMS, in the event that the RMS has exceeded the high-limit stop for any reason. This should only be used when bringing the RMS to a neutral position using the static pot. on the electronic control module. The span pot. should be dialed to 0.0 during this procedure.

- ° Start Roll & Pitch - Depressing this switch will reset the pneumatic switch to "ON" for roll and pitch and enable motion in these degrees of freedom.

- ° Start Yaw - Depressing this switch will reset the pneumatic switch to "ON" for yaw and enable motion in this degree of freedom.

- ° Start Yaw - Depressing this switch will reset the pneumatic switch to "ON" for yaw and enable motion in this degree of freedom.

- ° Low Limit-Override - Depression of this switch will override the vertical low-limit pneumatic switch, thereby restoring control of motion to the RMS, in the event that the RMS has exceeded the low-limit stop for any reason. This should only be used when bringing the RMS to a neutral position using the static pot. on the electronic control module for lowering the RMS. The span pot. should be dialed to 0.0 during this time.

- ° Vertical Start Key - Turning this key in a clockwise direction will reset the pneumatic switch to on for vertical and enable motion in this degree of freedom.

There are three red/green indicators above the start switches. From left to right they are roll and pitch, yaw, and vertical. The indicator will be "Red" if a pneumatic shutoff is in effect for that degree of motion and "Green" if motion is enabled.

5.1.2.4 Motion system. The motion system of the RMS is electrically controlled and hydraulically powered. The power system is a self-contained, fully integrated system including controls, reservoir, pump, accumulators, manifolds, filters, and a water-cooled heat exchanger.



Figure 5-1. Ride Motion Simulator

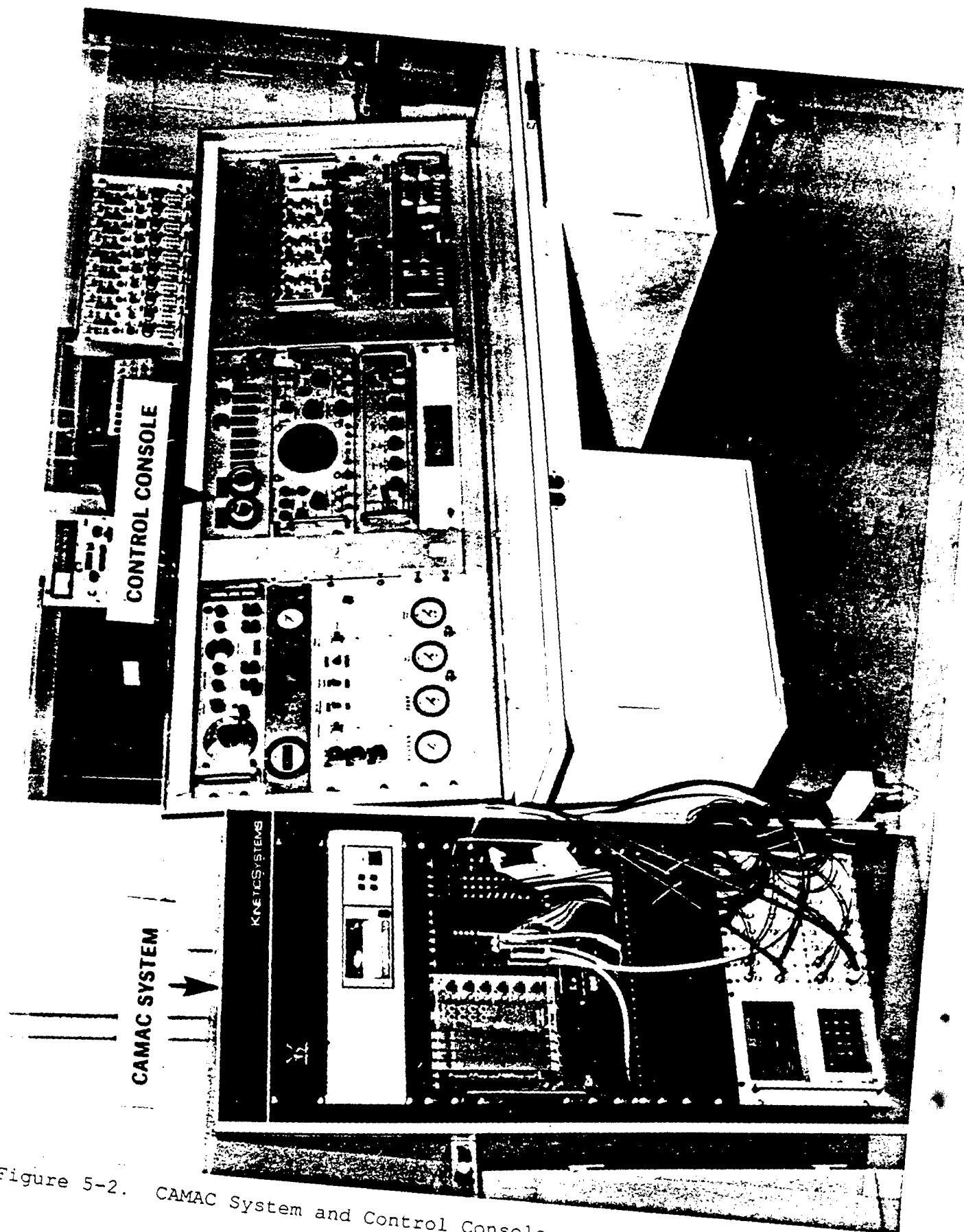


Figure 5-2. CAMAC System and Control Console

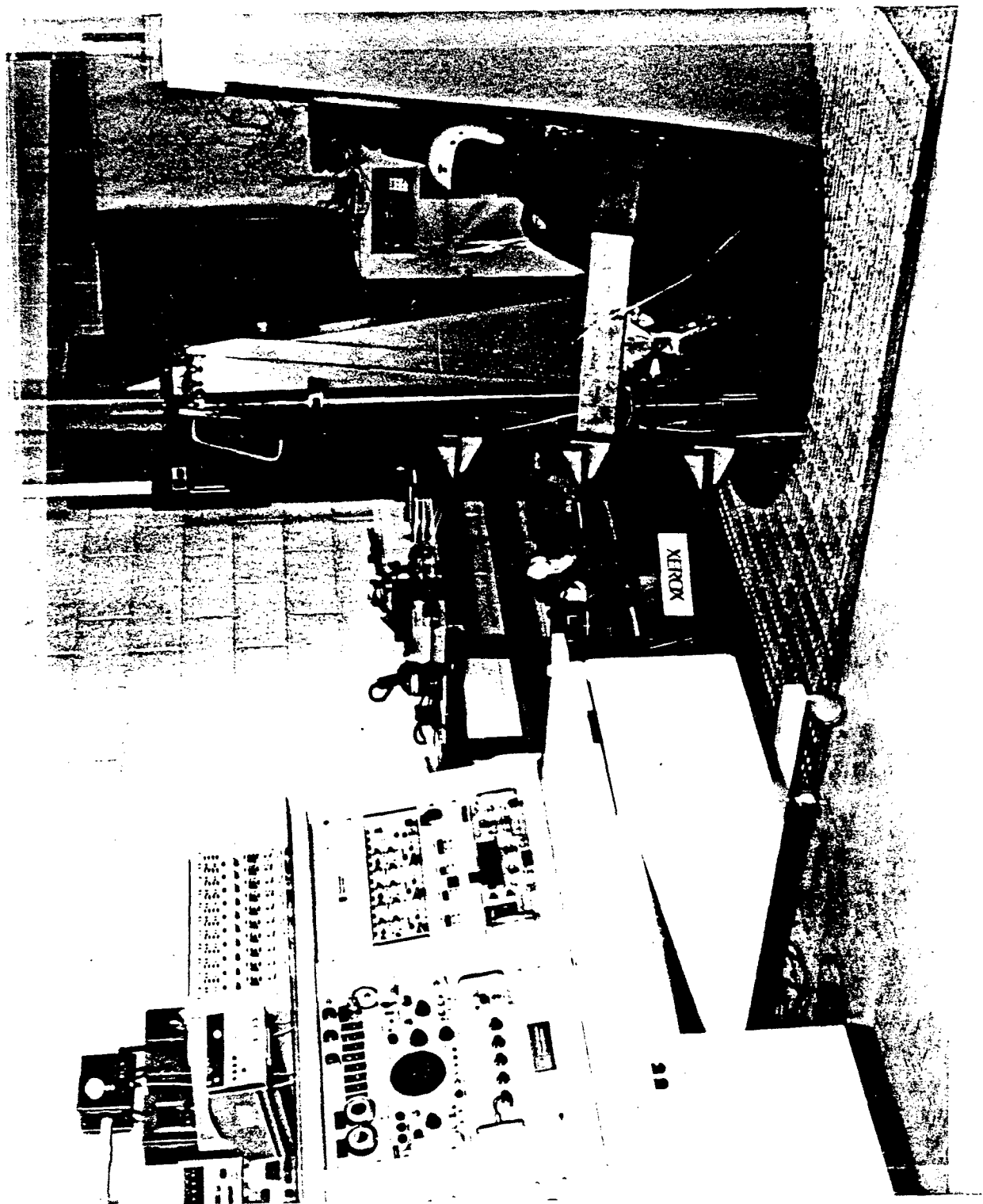


Figure 5-3. RMS Bay Room

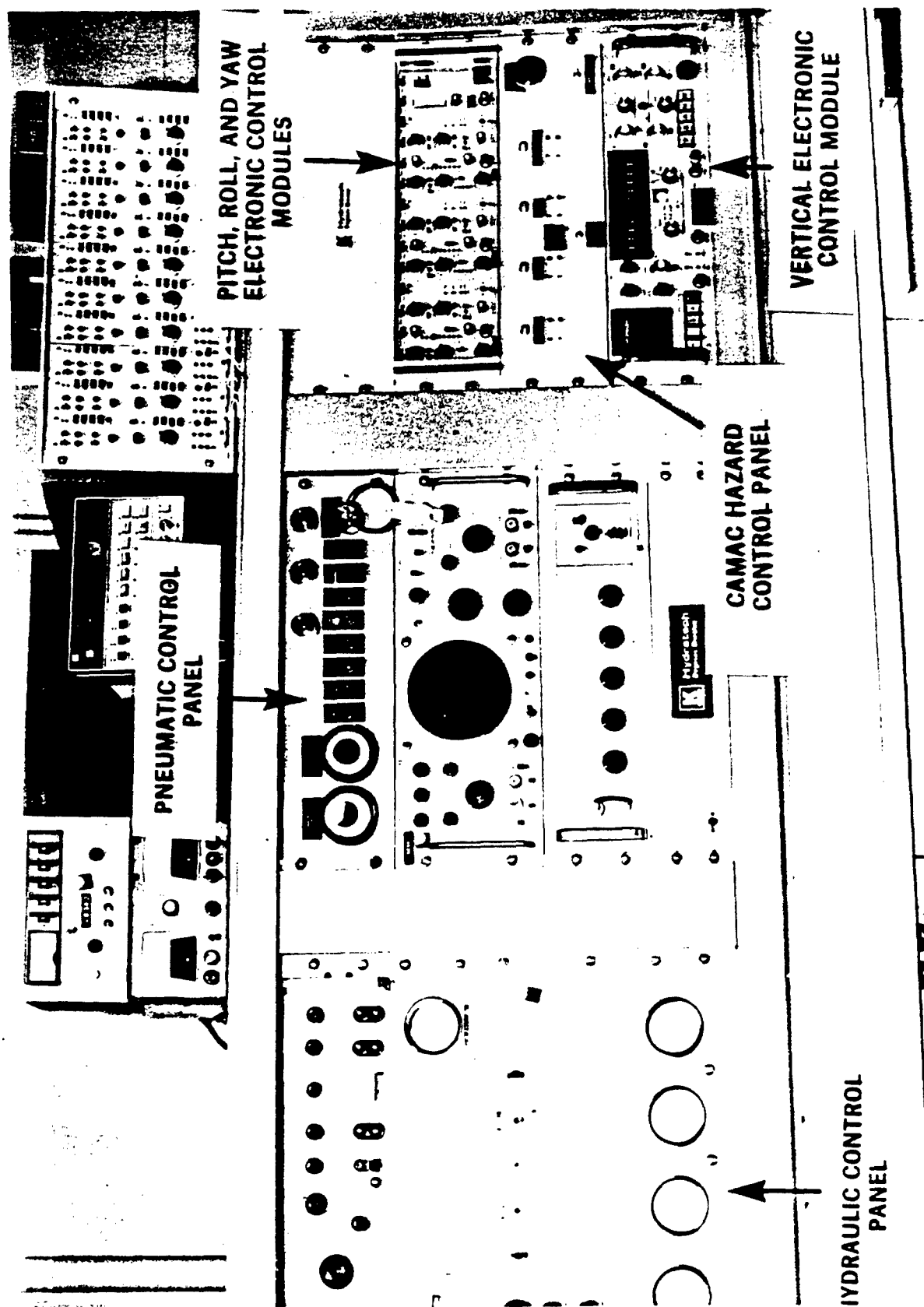


Figure 5-4. Control Console

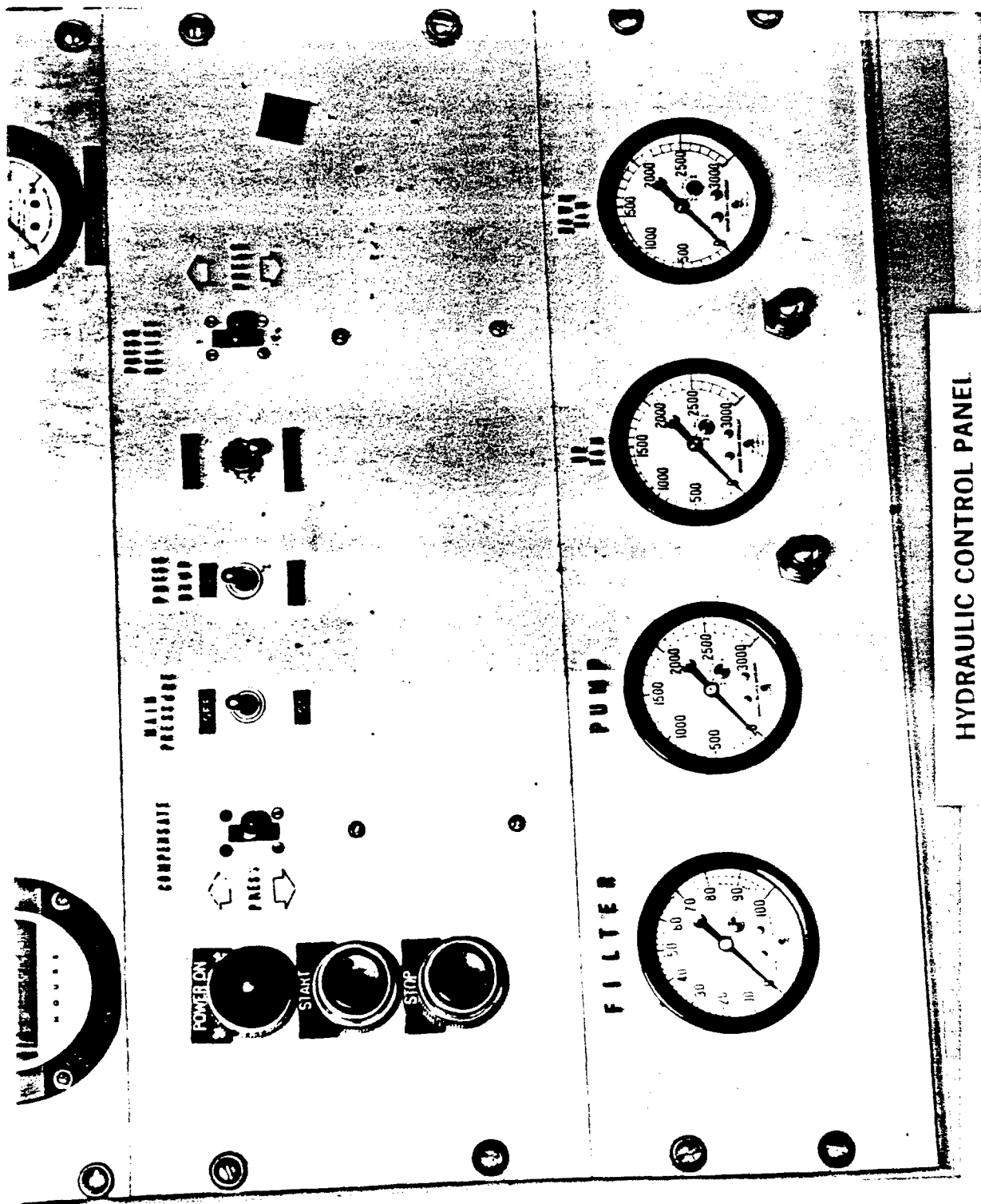


Figure 5-5. Hydraulic Control Panel

PNEUMATIC CONTROL PANEL

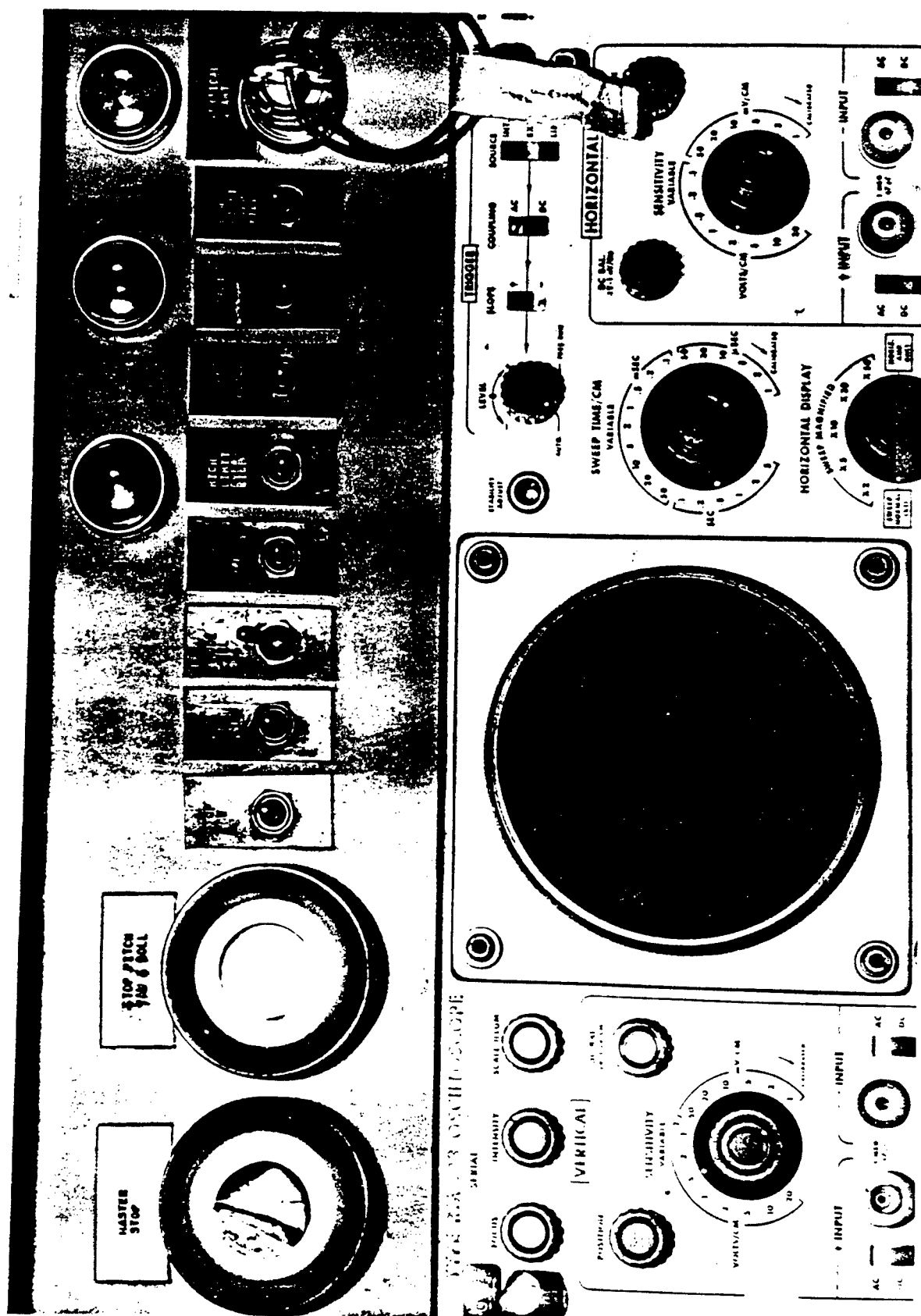


Figure 5-6. Pneumatic Control Panel



ELECTRONIC CONTROL MODULES

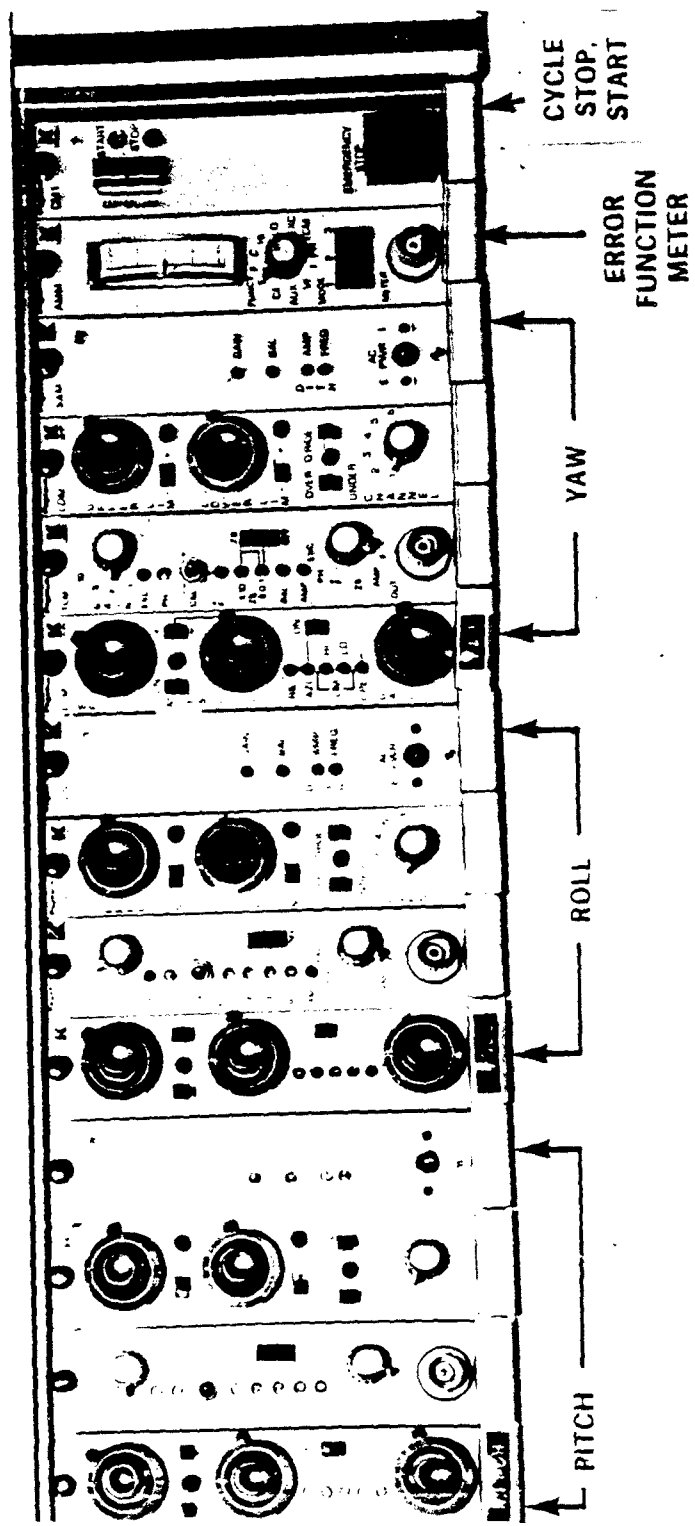


Figure 5-7. Electronic Control Modules (Roll, Pitch, Yaw)



Hydratech
Pegasus Division

VERTICAL ELECTRONIC CONTROL MODULE

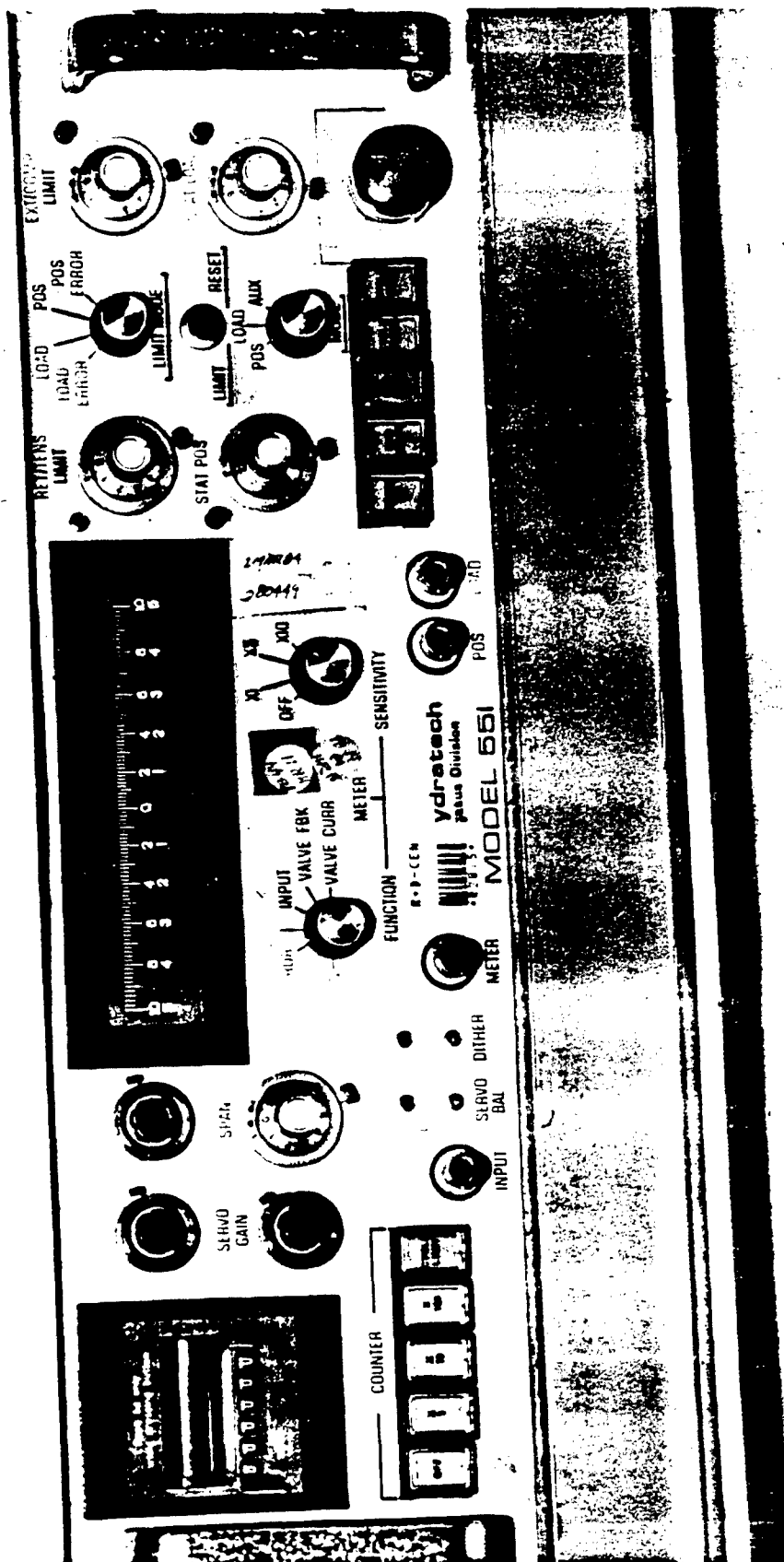


Figure 5-8. Vertical Electronic Control Panel

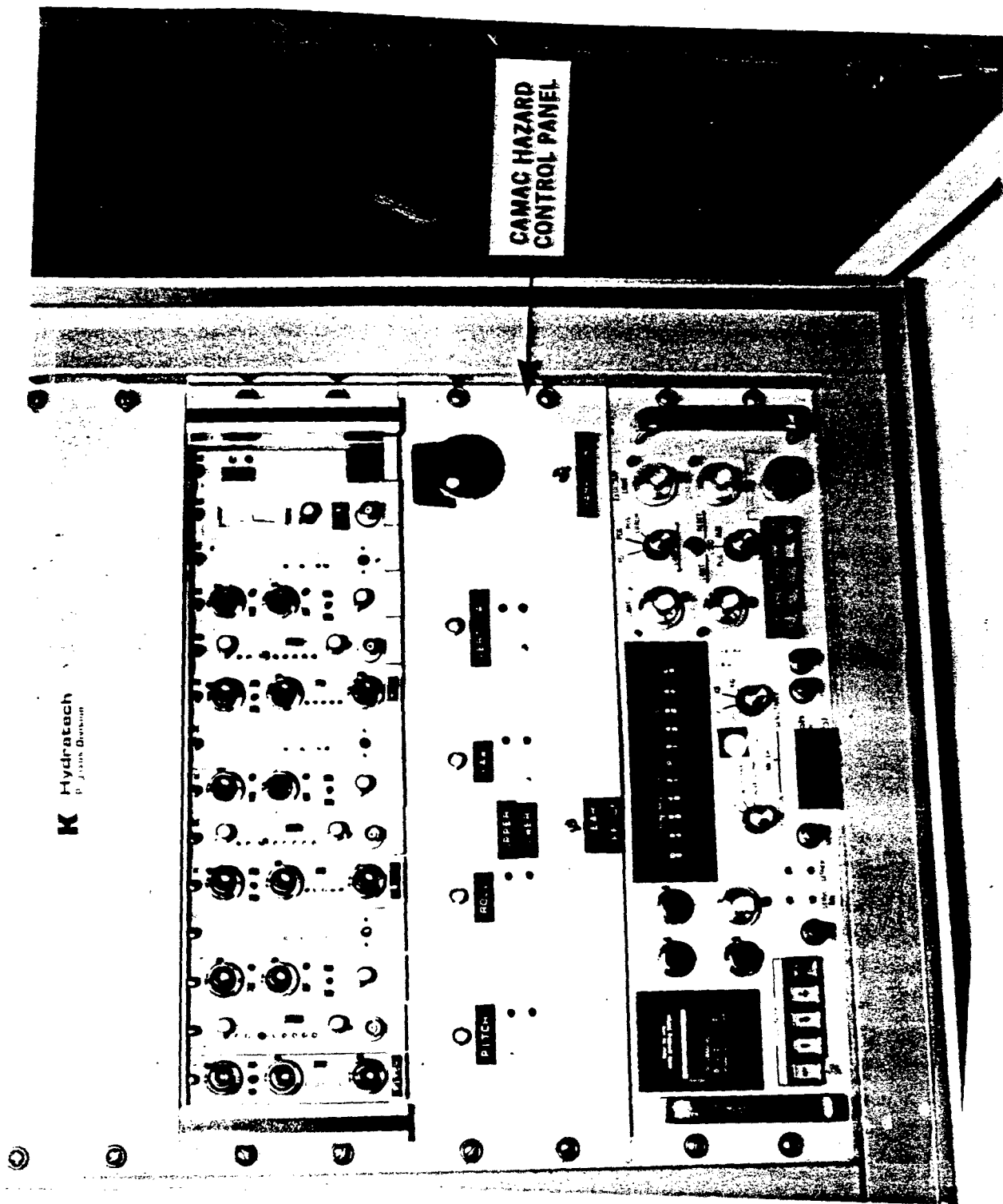


Figure 5-9. CAMAC Hazard Control Panel

The motion platform is pictured in its entirety and in various stages of disassembly in Appendix A. This platform supports a seat. For various vehicle simulations, different seats can be mounted to the platform.

Vertical motion is accomplished by two actuators. To calculate the maximum possible force in a given direction use the equation:

$$\text{Force} = [(\text{piston diameter}/2)^2 - (\text{rod diameter}/2)^2] * (\text{system pressure})$$

The up acting actuator has a 2-inch-diameter piston and the pressure acts on the piston head side, so that at:

- 1500 psi, maximum force = 4,712 lbs
- 2000 psi, maximum force = 6,283 lbs
- 3000 psi, maximum force = 9,425 lbs

The down actuator has a $1\frac{1}{8}$ -inch shaft diameter and a 1.5-inch piston. The net surface area is then 1.166 square inches so that at:

- 1500 psi, maximum force = 1,749 lbs
- 2000 psi, maximum force = 2,332 lbs
- 3000 psi, maximum force = 3,497 lbs

The pitch actuator has a $1\frac{1}{8}$ -inch shaft diameter and a 2-inch piston giving a surface area of 2.15 square inches. The lever arm is 13.5 inches long, so that at:

- 1500 psi, maximum force = 3,221 lbs
- 2000 psi, maximum force = 4,295 lbs
- 3000 psi, maximum force = 6,433 lbs

The roll actuator has $1\frac{1}{2}$ -inch shaft diameter and a 1-inch piston giving a surface area of 0.59 square inches. The lever arm is 9.5 inches long, so that at:

- 1500 psi, maximum force = 835 lbs
- 2000 psi, maximum force = 1,178 lbs
- 3000 psi, maximum force = 1,767 lbs

The yaw actuator has $1\frac{3}{8}$ -inch shaft diameter and a $1\frac{7}{8}$ -inch piston giving a surface area of 1.28 square inches. The lever arm is 9.5 inches long, so that at:

- ° 1500 psi, maximum force = 1,914 lbs
- ° 2000 psi, maximum force = 2,553 lbs
- ° 3000 psi, maximum force = 3,829 lbs

All of the actuators are position driven.

Detailed schematics of both the hydraulic and pneumatic systems are presented in Appendix B.

5.1.2.5. Hydraulic control panel. The hydraulic control panel (Figure 5-5) provides the operator control of the hydraulic system.

The description of the buttons and toggle switches are described as follows:

- ° Power On - The "Red" indicator will be lit up whenever the pump's circuit breaker is closed. The "Black" start push button turns on the pump and the "Red" stop button will turn off the pump.

- ° Pressure Compensator - This switch will adjust the pressure generated by the pump. Pushing the switch up will increase the pressure, and pushing it down will decrease the pressure.

- ° Main Pressure - This switch activates a blocking valve which will block hydraulic flow from the pump to the hydraulic system. In the "OFF" position, flow is blocked and in the "ON" position, the valve is open and power is applied to the system.

- ° Pressure Dump - This switch will direct hydraulic flow into the reservoir when in the "ON" position and into the hydraulic system in the "OFF" position.

- ° Bleed Valve - By pressing this switch up, pressure will be bled out of the accumulators and into the reservoir.

- ° Pressure Relief - This switch controls the position of the relief valve which limits pressure buildup in the system. This should be set by lowering its pressure setting until a high-pitched whine is heard (oil flowing through the relief valve), then raising the setting until the whine disappears. This control is used in conjunction with the pressure compensator control when it is desired to raise or lower the working pressure of this system. The system pressure is not changed as

a routine matter.

The description of the pressure gauges are as follows:

Filter - Indicates the pressure across the low-pressure filter. A pressure of 25 psi or higher would indicate a requirement for replacement.

Pump - Indicates the operating pressure of the hydraulic pump.

UP Ram - Indicates the hydraulic pressure applied to the "UP" vertical actuator.

DOWN Ram - Indicates the hydraulic pressure applied to the "DOWN" actuator.

5.2. Hazard Controls

The RMS has a total of eight pneumatic fail-safe devices, plus two sets of electronic travel limiters to protect humans from injury and valuable components from damage. These devices can be activated automatically by the test subjects, or by the RMS operator.

The following is a description of each safety device, how it works, and how it protects subjects and components.

5.2.1. Pneumatic Hazard Controls.

5.2.1.1. "Red" master stop button (operator controlled). Located on the pneumatic console (Fig 5-6) is a "Red" master stop button which is controlled by the operator. If the operator should see any uncommon happenings, he will press the button, which will deactivate blocking valves on all four degrees of freedom. This will stop hydraulic flow to the actuators, thereby stopping all motion of the RMS.

Refer to Sec. 5.5.2.1, Restart for Pneumatic Shutdowns.

5.2.1.2. "Black" stop roll, pitch, and yaw button (operator controlled). This button is located adjacent to the "Red" master stop button on the pneumatic control panel (Fig. 5-6). This button operates identically to the "Red" master stop button, except it does not stop vertical motion.

Refer to Sec. 5.5.2.1, Restart for Pneumatic Shutdowns.

5.2.1.3. Mode selection (subject controlled). There are three stop buttons located on the RMS. One is hand-held by the subject and the other two are located within arm's length. All three of these stop buttons cannot be used at the same time. The type of test determines the mode selected.

Dead Man's Switch - With the mode select switch in the "down" position, the dead man's switch (hand-held by the subject) is operational while the other two switches are inoperative.

The dead man's switch is normally open; it is activated by the subject releasing the stop button if he feels that he is in an unsafe condition. When the button is released, air pressure is released through a "quick exhaust valve," which in turn stops all RMS motion.

"Stop" Button Switches - These two switches are in operation when the mode select switch is in the "up" position. This leaves the dead man's switch inoperative. These switches are normally closed and are activated by pressing the stop button (one or the other) to stop all simulator motion. Motion is stopped by deactivating the hydraulic blocking valves, thereby stopping hydraulic flow to all actuators.

To restore motion, refer to Sec. 5.5.2.1, Restart for Pneumatic Shutdowns.

5.2.1.4. Upper and lower limit override switches (automatically activated). The upper and lower limit override pneumatic switches are safety devices that are automatically activated when the simulator travel exceeds a preset amount of movement in the vertical degree-of-motion. When the simulator activates the override switches (whether it be upper or lower), air pressure is released through the "Quick Exhaust Valve," which in turn deactivates the vertical blocking valve, stopping motion vertically.

To restore motion, refer to Sec. 5.5.2.1, Restart for Pneumatic Shutdowns.

5.2.1.5. Air pressure system (automatically activated). If air pressure is lost due to a break in an air line, the air pressure system fail-safe mode activates the quick-exhaust valve, thereby deactivating all blocking valves and stopping all motion.

The rider would dismount and repairs would be made to the air line.

5.2.2. Electrical Hazard Controls.

5.2.2.1. Solenoid valve (automatically activated). In the event that the main electrical supply is cut off to the console, the electrically operated solenoid valve will automatically divert the air supply flow through the quick-exhaust valve, which, in turn, activates the master valve, stopping all motion.

To restore movement, perform the following:

- ° Locate the cause of electrical power loss and repair it
- ° Perform the standard startup procedure

5.2.2.2. Electronic control panel limits (automatically activated). During operation, the seat travel in all four degrees of movement is continuously monitored by the control modules. If roll, pitch, or yaw travel exceeds a value preset by the operator, the limiter is activated, resulting in an automatic shutdown (cycle stop) of roll, pitch and yaw. Vertical travel is monitored separately but operates the same as the roll, pitch and yaw limiter.

To restore motion to the RMS, refer to Sec. 6.2.2, Restart for Electronic Controller Limits.

5.2.2.3. Uninterruptible power supply (UPS) (automatically activated). In the event of a loss of electrical power, UPS will provide battery backup power to the entire RMS system for up to 30 minutes.

In the case of a loss of power, the operator will use normal shutdown procedures for the RMS. After locating the cause of the problem and restoring the electrical power, the standard startup procedure will be used to restore the RMS operation.

5.2.3. CAMAC Hazard Controls.

5.2.3.1. Emergency shutdown "red" pushbutton switch (operator activated). Located on the CAMAC control panel (Fig. 5-9) is a "red" pushbutton switch which is controlled by the RMS operator. If he should see any uncommon happenings, he will press the pushbutton, which will lock the output signal from the CAMAC at its current value, thereby freezing the RMS at its present position. The operator then presses "cycle stop" and sets all the span pots to 0.0.

5.2.3.2. Ramp-down toggle switch (operator controlled). Located on the CAMAC control panel is a "ramp-down" toggle switch which is controlled by the RMS operator. If, for any reason, he wishes to stop the test but does not need to have a very sudden shutdown, he may operate this switch. This will cause the CAMAC to ramp the RMS to its neutral position from its current position. The operator then presses "cycle stop" and sets all the spans to 0.0.

5.2.3.3. Electronic travel limiters (automatically activated). The remainder of the CAMAC control panel consists of electronic travel limiters. Each degree of motion has two sets of green and red LED's, an input BNC connector which measures the position of the RMS, and an output BNC connector which lets the

CAMAC know if a travel limit has been exceeded.

When RMS travel is between preset position limits, the green LED's for that degree of motion will be turned on. When travel exceeds either the lower limit or the upper limit, the corresponding red LED will turn on, and a signal will be sent to CAMAC which will cause the RMS to halt motion immediately. The operator then will press "cycle stop" and dial all spans to 0.0.

5.3. Facility Configuration

5.3.1. RMS Location. The RMS is located in the RMS Bay Room in Bldg. 215. A layout of Bldg. 215 is presented in Figure 5-10. Bldg. 215 was constructed in 1972, with laboratory simulation as its major function. Upon completion of the building, the RMS was moved from Bldg. 200 to its present location in the RMS Bay Room. Most of TACOM's analytical and physical simulation is performed here, including track and suspension, subsystem, and full-scale simulation of vehicles. A map of TACOM in Figure 5-11 shows the location of Bldg. 215.

In the RMS Bay Room (Figure 5-12) the CAMAC System and controller panel are adjacent to the RMS. A strip-chart recorder is located next to the desk (on which the computer terminal resides), which is used to monitor the controller signals sent to the simulator. The other half of the room is occupied by Cray Research on-site personnel.

5.3.2. Emergency Facilities.

5.3.2.1. Fire. In case of a fire, personnel can use a Class B&C and a Class A fire extinguisher located on the wall adjacent to the RMS, and the base fire department may be called on Ext. 47117, using the wall phone near the door.

5.3.2.2. Injury. To treat a minor injury, the injured employee may be taken to the dispensary which is located in Bldg. 2. For a serious injury, the TACOM ambulance from Bldg. 205 can be called (Ext. 47117). The base ambulance operates 24 hours a day and services South Macomb Hospital (distance : 2 miles) or Bi-County Hospital (distance : 3.5 miles).

5.4. Facility Maintenance

5.4.1. Maintenance Philosophy. In general, the operator is not the maintainer. Upon detection of faulty or suspicious operation, the operator must shut down testing and call on those personnel who are qualified to service the general class of components of which the system is composed. Operator investigation is limited to determining if the SOP has been observed. In the event no errors are found, system malfunctions fall into the following general classes:

° Mechanical, structural. These include broken welds, broken bolts, cracks in structural members (fatigue failures or single impact damage), broken anchor points for hydraulic actuators and misalignment of components due to the loosening of clamping devices.

° Mechanical, nonstructural. These include bending or fracturing of the mechanical portion of hydraulic components (cylinders, rods, rod anchors, manifolds, valve housings), damaged support brackets for transducers or limit switches, clamps for pneumatic and hydraulic hoses.

° Hydraulic. These include leaking fittings/hoses and rod seals, sticking servo valves, sticking directional valves, sticking relief valves, or pump compensator controls, leaking accumulator bladders and clogged filters.

° Electrical. These include motor wiring, circuit breakers, motor starters, panel wiring for switches, wiring to transducers, wiring to servo valves and the uninterruptible power supply (UPS).

° Electronic. These include data files, signal conditioning equipment, electronic control modules, signal and position monitoring circuits, cabling, CAMAC or the Micro-VAX II computer.

° Pneumatic. These include leaks in tubing or fittings, kinked tubing, sticking valves and the loss of air pressure.

5.4.2. Preoperation/postoperation checks. During periods of steady use, execution of the Standard Operation Procedure (SOP) is itself a preoperation check for the correct functioning of the RMS. It begins with turning on the electronic equipment and concludes with a trial run (i.e., without occupant) immediately prior to actual testing with live subjects.

5.4.3. Periodic exercising of the RMS.

° Exercising of the RMS is required monthly.

° The first step in the exercise cycle is to verify the quantity of oil in the reservoir. Descend into the RMS pit and read the sight glass located on the reservoir tank. The main pump and motor are mounted on the reservoir tank. Oil must show in the sight glass. If not, add oil.

° Visually inspect the floor of the pit and the surrounding gutter for signs of oil accumulation. Accumulations of oil showing a liquid surface must be wiped up or washed away with solvent. Remove liquid oil, or oil and solvent, in the gutter.

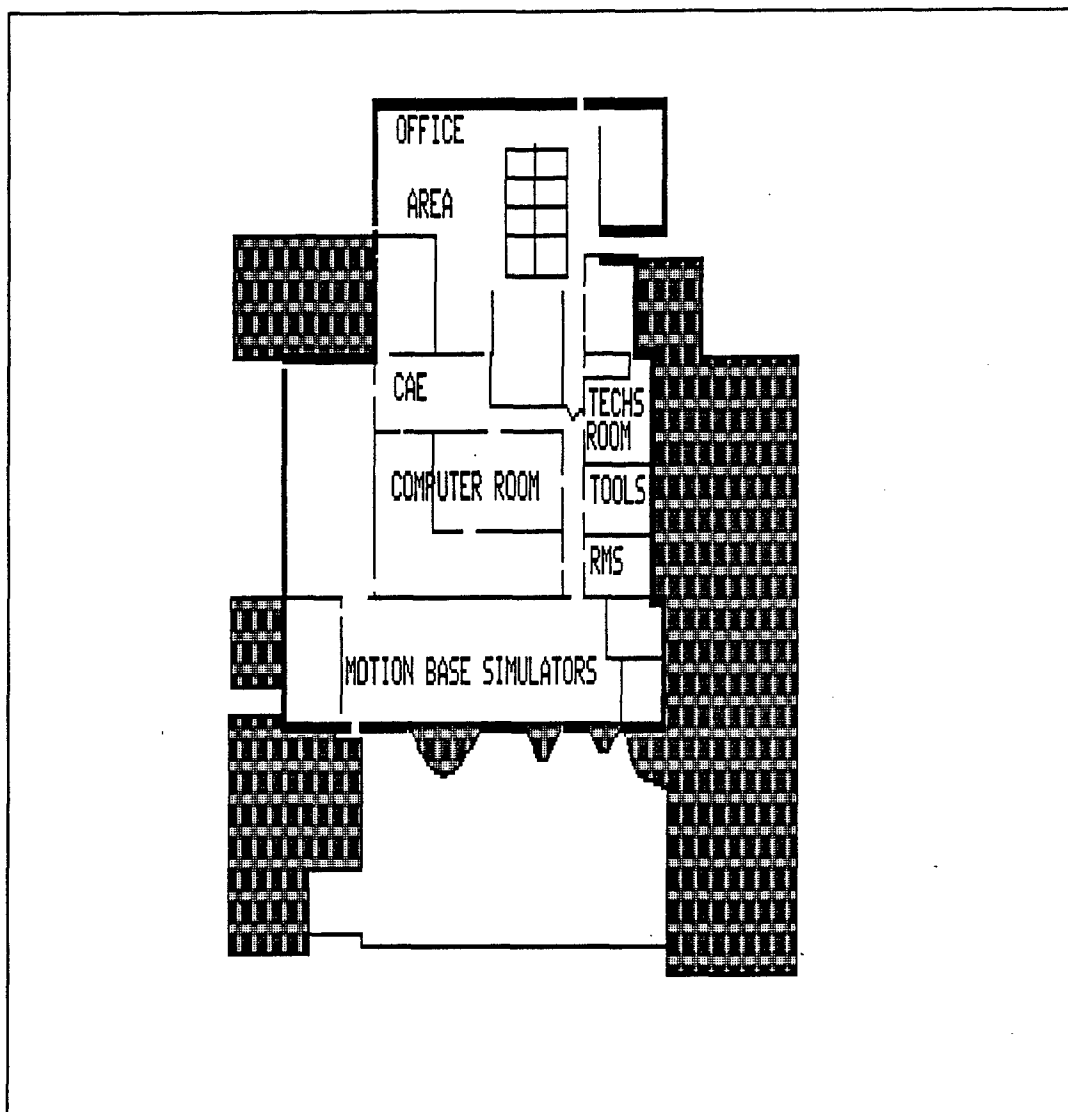


Figure 5-10. Layout of Building 215.

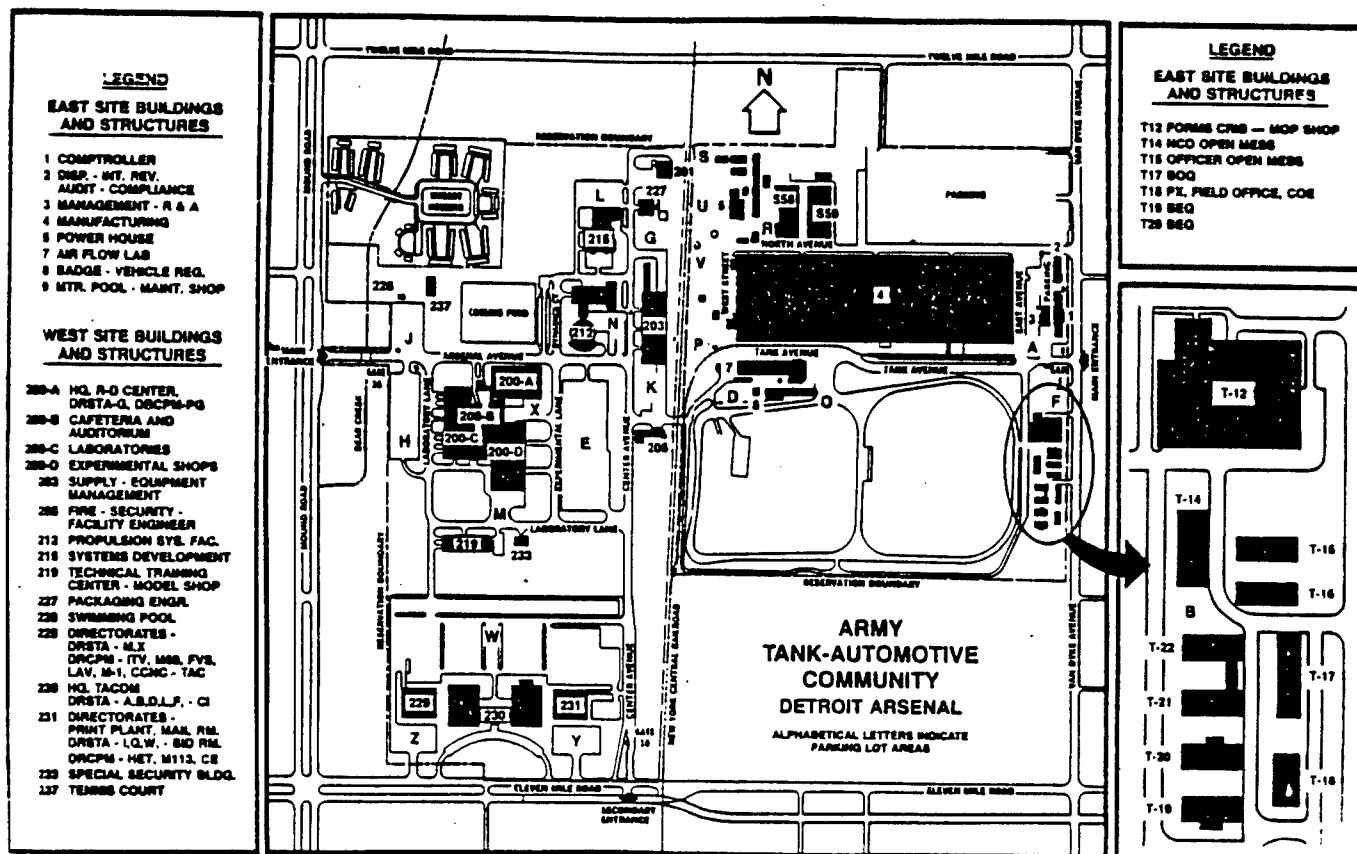


Figure 5-11. TACOM Map.

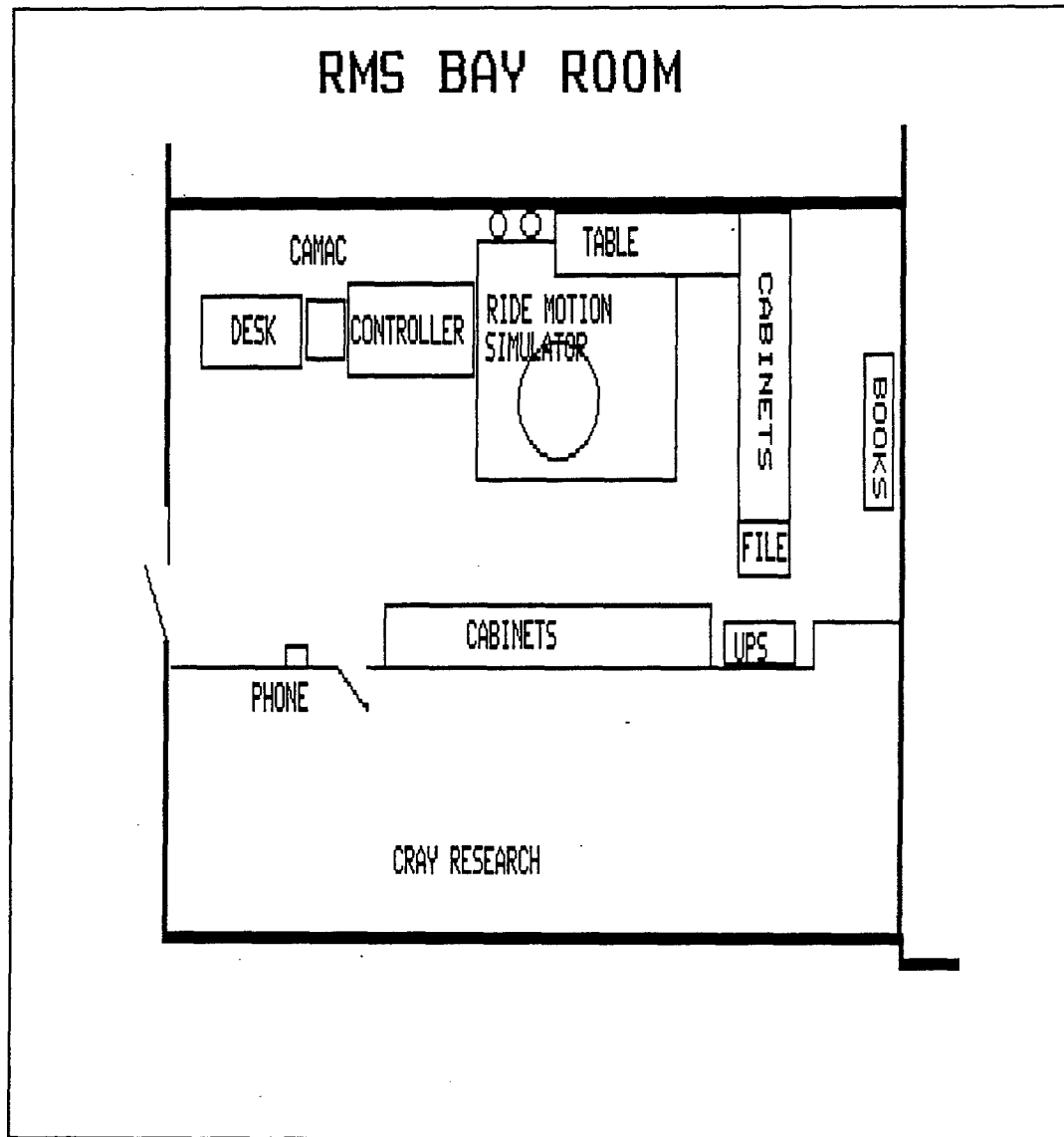


Figure 5-12. Layout of the Ride Motion Simulator Room.

A damp oil film is acceptable.

- ° Visually inspect all the piping and components in the pit for accumulations of oil. Wipe off as required. Inspect components which are found to be chronically wet. Notify the technician staff for further inspection and repair or both.

- ° Start up the RMS in accordance with the SOP. Operate the RMS for half an hour with typical profile inputs. Watch for unexpected or erratic operation. Shut down system in accordance with SOP.

- ° During periods of constant use, the monthly exercise period can be bypassed but not the pit inspection.

5.4.4. Annual inspection. Inspect the entire RMS structure for signs of mechanical deterioration or failure. Notify the technician staff in the event problems are uncovered. The annual inspection may be combined with a monthly exercise period for the month in which the inspection is conducted.

5.4.5. Maintenance manuals.

5.4.5.1. Hydraulic equipment. Maintenance manuals, as such, do not exist for the hydraulic components. All the hydraulic components are conceptually simple but precise devices (built to very close tolerances). General knowledge of hydraulic equipment is sufficient to deal with minor problems. If a major failure occurs, the component may be replaced with a new item, or it may be sent back to the manufacturer for rebuilding. The pumps and valves date from approximately 1960. Some components are no longer manufactured.

5.4.5.2. Pneumatic equipment. Maintenance manuals do not exist for this equipment. It, too, is very simple in concept. Technicians familiar with hydraulic equipment can service pneumatic devices. However, the replacement cost of these devices are so low that they are generally replaced rather than repaired.

5.4.5.3. Control console components. The manuals of various modules and CAMAC theory are located in a black cabinet inside the RMS room. If a module fails, it must be sent to the manufacturer for repair.

The schematics for the CAMAC Safety Monitor circuitry are located in Appendix F. If the circuitry fails, an engineer must perform troubleshooting and repair it.

There are no manuals for the electronic filters. If one happens to fail, simply replace it with a spare filter. Contact a member of the Physical Simulation Group (AMSTA-RYA) for help.

5.4.6. Records.

5.4.6.1. RMS log book. Each use of the RMS will be recorded in this log book, which will be kept at the control console. Each entry will include the following items:

- Date of use.
- Startup time, from turning on the power.
- Shutdown time, to turning off the power.
- Operator's name and signature.
- Remarks - Any information concerning the condition of the RMS itself and the purpose for which it was used or both.

5.4.6.2. Inspection/maintenance. Each monthly exercise/inspection, each annual inspection, and each maintenance action will be recorded in the RMS Log Book, which will be kept at the control console. Each entry will contain (as appropriate), the following items:

- Date.
- Type of action: exercise, inspection or maintenance.
- Startup time, from turning on the power.
- Shutdown time, to turning off the power.
- Description of maintenance, stating specific actions taken and on which component(s).
- Results of an inspection.
- Remarks - Any information of interest, not specifically requested by the other headings in the log book.
- Operator's/inspector's/maintainer's name and signature.

5.4.6.3. RMS log book review. The log book entries must be reviewed quarterly to verify that the RMS is being properly used and maintained and that the entries are being made in accordance with the instructions provided above.

The review will be conducted by the project engineer assigned to manage the operation of the RMS and his/her supervisor. Both individuals will sign and date the log book upon completion of the review.

5.5. Standard Operating Procedures

5.5.1. Starting Procedures.

Step 1. Execute the computer program which will drive the RMS. This program is located on the Micro-VAX II in the RMS room and is stored in the account \$disk1:[USER] under the name SEAT.FOR. This program will guide the operator step by step through the SOP. Execute the program by typing "SEAT" upon login.

Step 2. Notify the ambulance (x47117) of the upcoming test.

Step 3. Turn on the electronics. Allow 20 minutes warm-up time per manufacturer's instructions.

Step 4. Pressurize the pneumatic system. A manually operated valve is located on the wall behind the control console. The air pressure must not be less than 75 psi. The gauge is located on the left third of the control console, one rack panel down from the top (Fig 5-5).

Step 5. Turn on the coolant pump by means of the switch box on the wall behind the control console. Close the circuit breaker first, then push the start button.

Step 6. Close the circuit breaker for the main pump motor. The breaker is located on the wall above the work bench. The red indicator light on the left side of the hydraulic control panel will light up.

Step 7. Ensure that the span pots. for all four degrees of motion on the electronic control modules are set to 0.0. The electronic control modules are located on the right third of the control console (Fig. 5-7 and 5-8).

Step 8. Check the inputs to the electronic control modules from the CAMAC via the electronic filters. These filters are preset to 10 Hz. Connections should be made as follows:

<u>Channel</u>	<u>Degree of Motion</u>
1	Vertical
2	Roll
3	Pitch
4	Yaw

Verify the CAMAC hazard control connections from the box to the strip on the back of the CAMAC. See Appendix G.

Step 9. Set the pitch, roll, and yaw meter function switch to "E" for detecting the position error signals. The switch is located on the right-hand side of the roll, pitch, and yaw control module (Fig. 5-7).

Step 10. Ensure that the static pots. for the roll, pitch, and yaw motions are set to 0.0. The static pots. are located on the electronic control modules (Fig. 5-7).

Step 11. The following switch settings on the vertical electronic control module must be set as follows:

- 1) Meter function switch to "POS ERROR."
- 2) Meter sensitivity switch to "X1" setting.
- 3) Static position pot. to "1.13."
- 4) Mode switch to "POS."
- 5) Limit mode switch to "POS."

Step 12. Ensure the main hydraulic pressure control switch is in the "OFF" position (up). This will block any hydraulic flow from the pump to the system. The switch is on the left third of the console, midway up from the bottom (Fig. 5-5).

Step 13. Ensure that the pressure dump switch is in the "ON" position (up). This will divert any flow from the pump back to the reservoir. This switch is on the same panel as the main hydraulic pressure control switch (Step 12).

Step 14. Start the motor for the main hydraulic power supply. Press the large black pushbutton on the left side of the hydraulic control panel.

Step 15. Move the pressure dump switch to "OFF." Wait for pressure to build up to operation level (1300 to 1800 psi).

Step 16. Pressurize the system by moving the main pressure switch to "ON." Wait for the roll, pitch, and yaw error signals to go to "Zero." This is monitored on the meter by flipping the switch located below the meter from "1" pitch, to "2" roll, and "3" yaw.

Step 17. To adjust hydraulic pressure, use the compensator and pressure relief switches on the hydraulic control panel. The compensator is a system inside the pump which controls the pressure the pump can produce up to the design limit of the pump. The relief valve is an independent device in the system which limits the pressure buildup in the system. The correct adjustment for the two devices is to have the compensator pressure set just below the cracking pressure of the relief valve. To check the setting of the relief valve, lower its pressure setting until a high-pitched whine is heard (oil flowing through the relief valve) then raise the setting until the whine disappears.

Step 18. Check and ensure that the roll, pitch, and yaw error signals are still "Zero." Verify this on the meter on the right-hand side of the electronic controllers. If the limit light is lit up on the vertical controller, press the limit reset button. On the roll, pitch, and yaw controllers, if any of the red "Limit" LED's are on, flip the limit on switch "up" and "down" to clear these limits.

Step 19. Toggle the "START PITCH AND ROLL" switch (located on the pneumatic control panel) to energize the pitch and roll blocking valve. There is hydraulic pressure on these channels now. Yaw is energized by toggling the "START YAW" switch. The red indicators will flip to green when the respective channels are energized.

Step 20. Press the "Low Limit Override" toggle switch (located on the pneumatic control panel) and hold. This will energize the vertical blocking valve and consequently flip the red indicator to green.

Step 21. Raise the simulator by increasing the static position pot. on the vertical controller to (4.57) mid-position. Look at the two strips of tape on the left side of the RMS to confirm that they are even. This confirms that the RMS is in mid-position.

Step 22. Release the "Low Limit Override" switch and reset the lower pneumatic safety switch on the left side bottom of the RMS. This will de-energize the vertical blocking valve and the vertical indicator will flip back to red.

Step 23. Turn the vertical start key on the pneumatic control panel clockwise and back. This activates the vertical blocking valve and resets the vertical indicator to green. The vertical channel is now engaged.

Step 24. Test the CAMAC switches and limits in the order dictated by the computer program. Use the static pots. to move the RMS to extreme positions and toggling of the CAMAC shutdown switches. Clear the limits when appropriate (Fig. 5-9).

Step 25. Place the RMS back into its neutral position by dialing the roll, pitch, and yaw static pots. to 0.0 and the vertical static pot. to 4.57. If the limit light is lit up on the vertical controller, press the limit reset button to clear it. If any of the red "Limit" LED's on the roll, pitch, or yaw controllers are on, flip the "Limit On" switch up and down to clear these limits. Clear the CAMAC limits, if necessary.

Step 26. Turn on the strip-chart recorder to monitor the input signal. Press carriage return to perform one simulation of each profile.

Step 27. Press the cycle start button on the far right side of the roll, pitch, and yaw electronic control modules. The red LED will turn off and the green LED will come on. Then press the cycle start button on the bottom right side of the vertical electronic control modules. That will illuminate green, and the cycle stop button will darken. Dial all spans to 10.0 (refer to Fig. 5-8 for these steps). The system is now ready for use.

Step 28. Start the trial run on the computer. Monitor this on the strip chart recorder. Look for any unacceptable movements or limit violations.

Step 29. When the trial run is complete, dial all span pots. to 0.0 and press cycle stop on both controllers (Figs. 5-7 and 5-8).

Step 30. Press the vertical Low Limit Override pneumatic toggle switch and hold. Dial the vertical static pot. to 1.13, thus lowering the RMS. Release the toggle switch and the green vertical indicator will flip to red.

Step 31. Ensuring that the rider wears the proper headgear, board him/her into the RMS.

Step 32. Press the vertical Low Limit Override pneumatic switch and hold, causing the vertical indicator to flip from red to green. Dial the vertical static pot. to 4.57, thus moving the RMS to its neutral position.

Step 33. Release the Low Limit Override switch (causing the vertical indicator to flip to red) and reset the lower pneumatic safety switch on the left-side bottom of the RMS. Turn the vertical start key clockwise and back, thus changing the vertical indicator to green. The vertical channel is now engaged.

Step 34. Press the Limit Reset button on the vertical controller to clear the extension and retention limits.

Step 35. Press the cycle start buttons on both controllers and dial all spans to 10.0. Clear the CAMAC limits.

Step 36. Start the simulation on the computer. Be alert for any problems.

Step 37. When the simulation is complete, dial all span pots. to 0.0 and press cycle stop on both controllers.

Step 38. Press the vertical Low Limit Override pneumatic switch and hold. Dial the vertical static pot. to 1.13, thus lowering the RMS.

Step 39. Release the Low Limit Override switch, thereby disengaging the vertical channel. Press the "Black" Stop Roll, Pitch, and Yaw button on the pneumatic control panel, thus disengaging these channels.

Step 40. Carefully, help the test subject dismount.

Step 41. Flip the main pressure switch on the hydraulic control panel to "OFF." This will block hydraulic flow to the RMS.

Step 42. Flip the pressure dump switch to the "ON" position. This will reroute the hydraulic flow to the reservoir.

Step 43. Turn "OFF" the hydraulic pump by depressing the black button on the left-hand side of the hydraulic control panel.

Step 44. Hold the bleed valve switch down until pressure is bled out of the actuators. Check the pressure gauge (Fig. 5-5) to verify this.

Step 45. Turn "OFF" the main pump breaker and the electronics.

Step 46. Turn "OFF" the recirculating pump.

Step 47. Turn "OFF" the air.

5.5.2. Restart Procedures.

5.5.2.1. Pneumatic shutdowns.

Step 1. Press the cycle stop button on both controllers.

Step 2. Dial all span pots. to 0.0.

Step 3. Adjust the vertical static pot. to set the position error voltage to -1.84 volts. This will correlate the actual position of the seat where the vertical controller thinks it should be. When we energize the vertical channel, the RMS will not "jump" into the position where the controller is pointing.

Step 4. To abort the test -

- Press the RED pneumatic master stop button located on the pneumatic control panel. This will disengage all channels of motion.

- Press and hold the corresponding vertical limit override switch.

- Dial the vertical static pot. to 1.13, thus lowering the RMS to its reset position.

To continue the test -

- Press and hold the corresponding vertical limit override switch.
- Dial the vertical static pot. to 4.57, thus moving the RMS to its neutral position.
- Release the limit override switch and reset the tripped limit.
- Reactivate vertical motion by turning the vertical start key clockwise and back.
- Press cycle start on both electronic controllers.
- Dial the span pots. to 10.0 and continue the test.

5.5.2.2. Electronic controller limits exceeded.

Step 1. Press "CYCLE STOP" on both controllers.

Step 2. Reset the limits.

Step 3. Dial all the span pots. to 0.0.

Step 4. If the error has been corrected, then -

- 1) Press "CYCLE START" on both controllers.
- 2) Dial all the span pots. to 10.0.

If the error has not been corrected, follow standard shutdown procedures.

5.5.2.3. CAMAC position limits and shutdown switches activated

Step 1. Press "CYCLE STOP" on both controllers.

Step 2. Dial all the span pots. to 0.0.

Step 3. If the error has been corrected, then -

- 1) Clear the CAMAC limits by using the toggle switch on the CAMAC panel.
- 2) Restart the CAMAC program. Skip down to Step 24, (Step 23 in the computer guide).
- 3) Follow the computer's instructions to finish the test.

If the error has not been corrected, follow standard

shutdown procedures.

5.5.3. Boarding Personnel Into Simulator.

Step 1. Perform a subject briefing. Instruction will include use of the pneumatic safety switches (deadman's or press-to-activate) and the goals of the test.

Step 2. After Step 28 of the starting procedure has been completed (ensuring all safeties work), have the rider (with assistance) climb into the simulator.

Step 3. The operator must keep a close watch on the simulation and, in the event something does not seem correct, be prepared to press the "RED" Master Stop pneumatic button.

5.5.4. Shutdown Procedures, Normal Operation.

Step 1. Press "CYCLE STOP" on both controllers.

Step 2. Dial all span pots. to 0.0.

Step 3. Press the "BLACK" Stop Roll, Pitch, and Yaw pneumatic button to deactivate these degrees of motion.

Step 4. While pressing the "Low Limit Override" switch, dial the vertical static pot. to 1.13, thus lowering the seat. Release the "Low Limit Override" switch.

Step 5. Dismount the test subject.

Step 6. Move the main pressure switch to the "OFF" position. This will block any hydraulic flow to the system.

Step 7. Move the dump pressure switch to the "ON" position. This will redirect all hydraulic flow to the reservoir.

Step 8. Turn off the pump by pressing the "RED" button on the hydraulic control panel.

Step 9. Depress the bleed-valve switch until pressure is bled out of the system.

Step 10. Turn "OFF" the main pump breaker and the electronics.

Step 11. Turn "OFF" the recirculating pump.

Step 12. Turn "OFF" the air.

5.6. Proficiency of Operators

5.6.1. Qualification. In order to qualify as a RMS operator, the candidate must:

a. Demonstrate a satisfactory knowledge of the associated hydraulic, mechanical, pneumatic, and CAMAC systems. Included in this is a thorough understanding of the RMS's various limit controls, the types of input signals used in operating the systems, and how to use the CAMAC to drive the RMS.

b. Demonstrate a thorough knowledge of how to operate the RMS, concentrating on the standard operating, shutdown and restart procedures as listed in Section 5.5. in this manual.

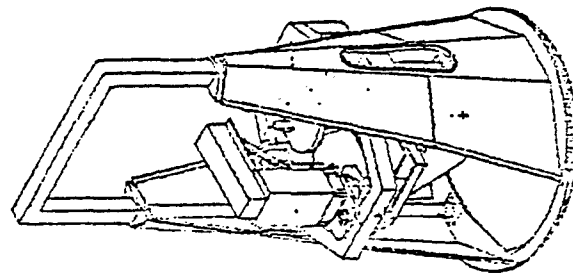
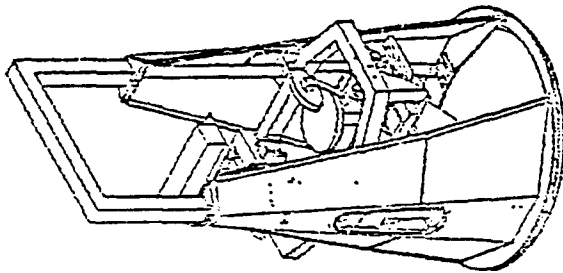
c. Receive 8 hours of hands-on training from a qualified RMS operator. This will be followed by a thorough test where the candidate will perform all facets of the standard operating procedures (along with restart and shutdown procedures).

5.6.2. Maintaining Operator Status. Along with retraining which results from tests conducted using the RMS, the monthly exercising of the RMS will provide sufficient refresher training.

APPENDIX A

3-D MODEL OF THE SEAT SIMULATOR

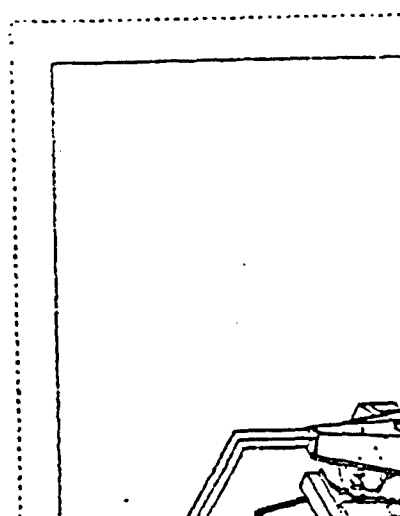
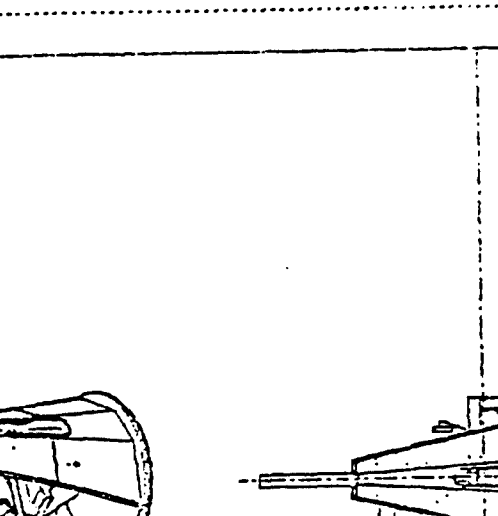
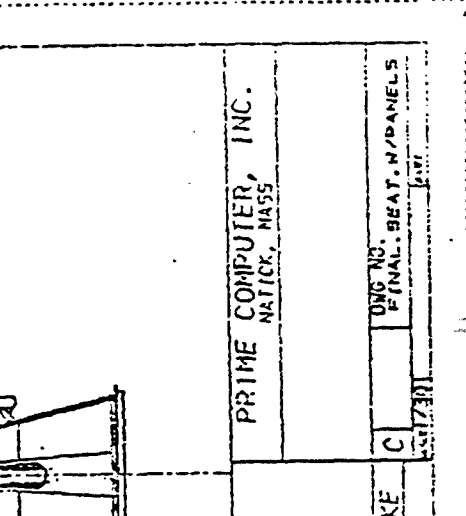
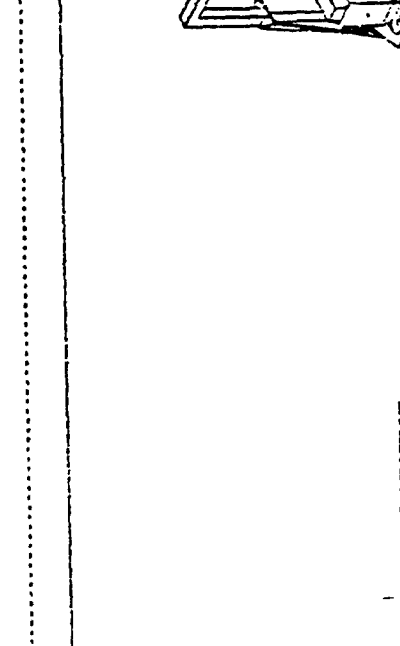
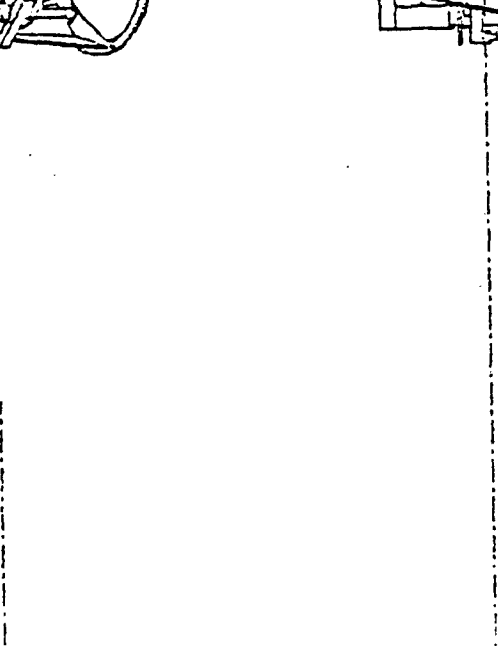
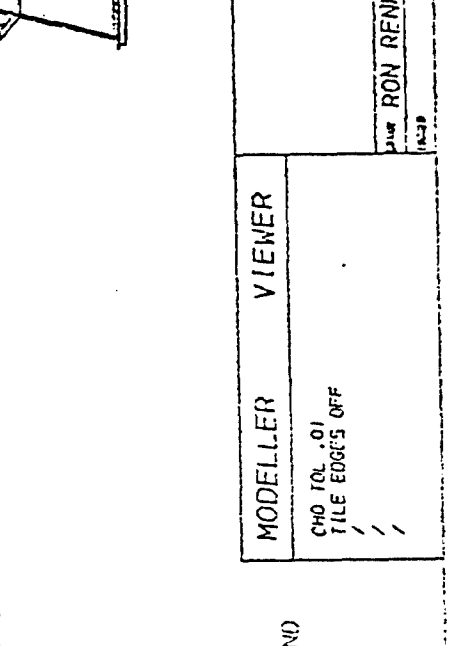
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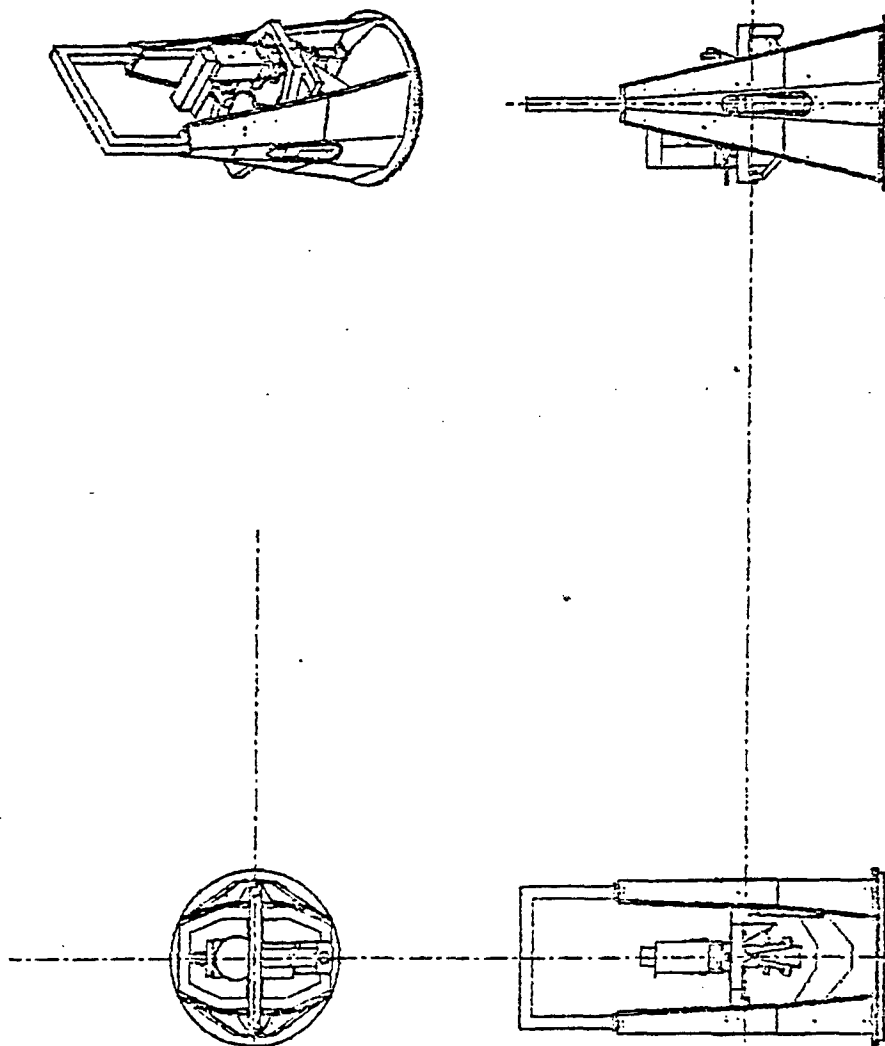
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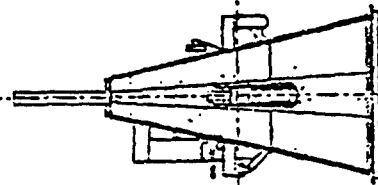
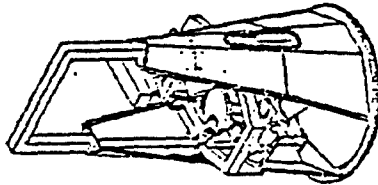
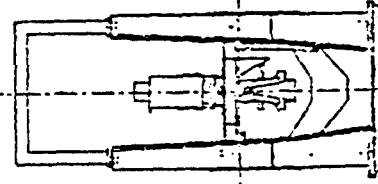
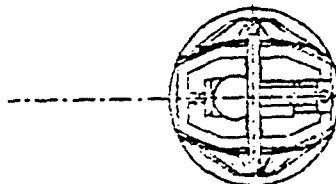
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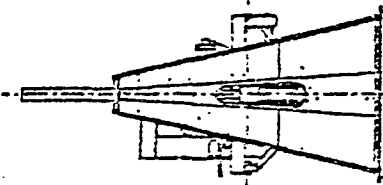
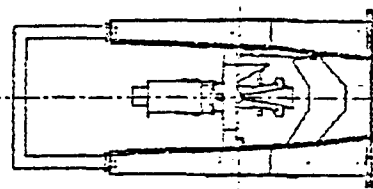
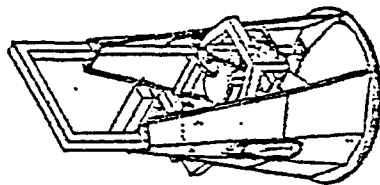
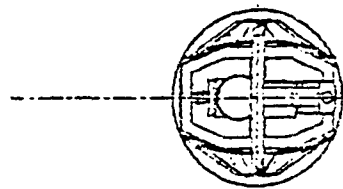
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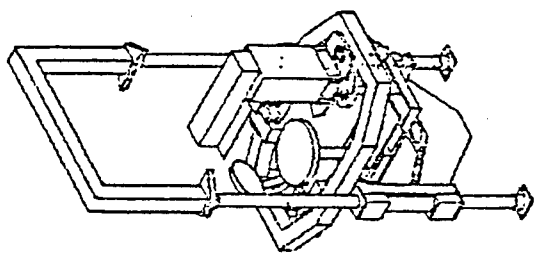
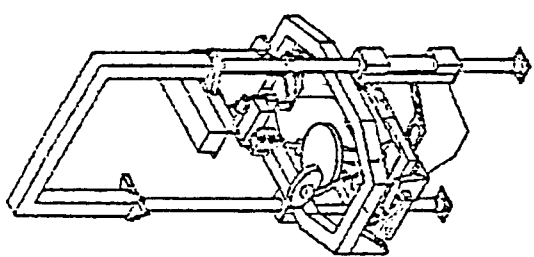
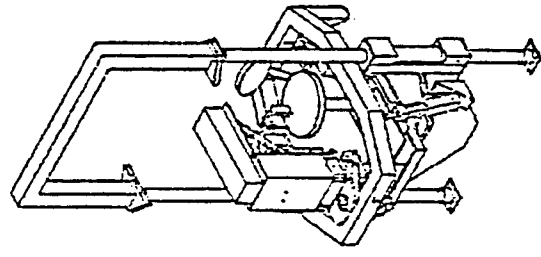
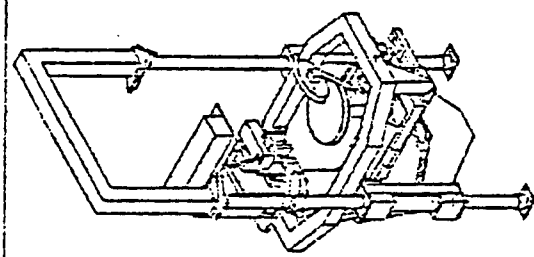
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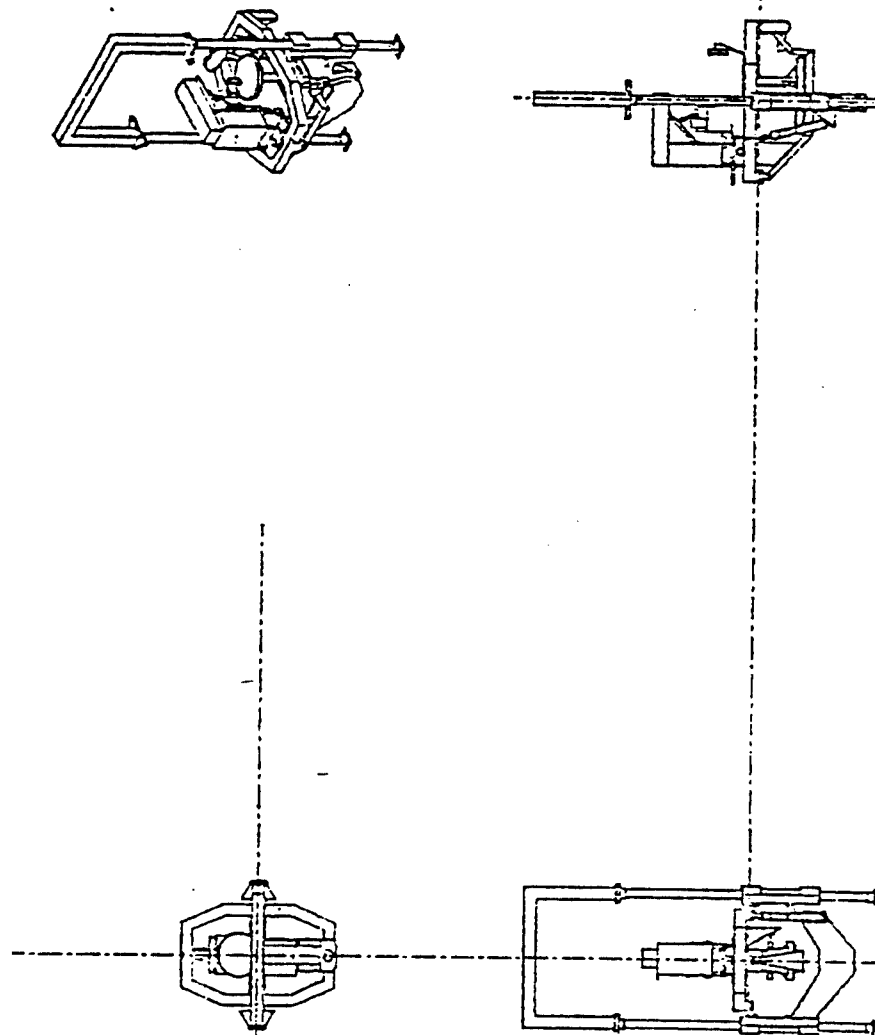
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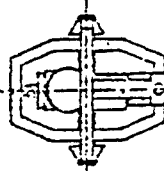
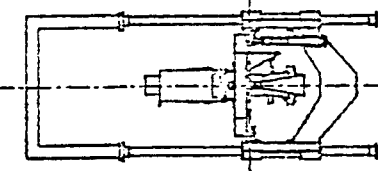
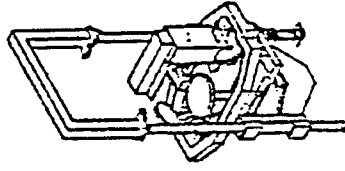
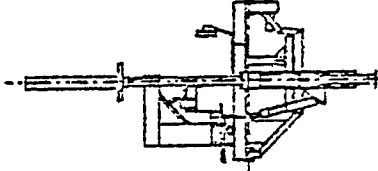
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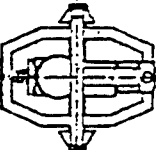
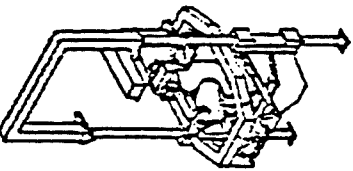
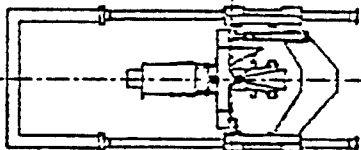
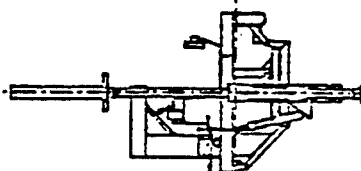


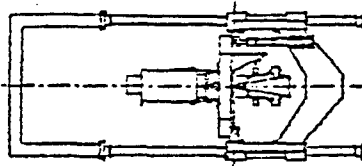
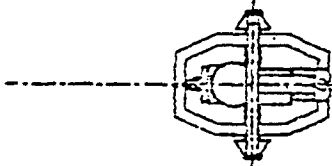
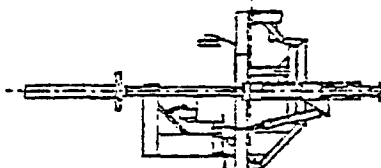
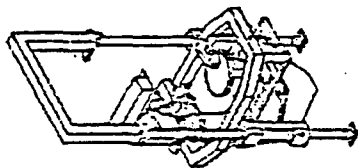
NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS	
C/D TOL. .01 TILE EDGES OFF / / /		RON RENKE	DWG NO. FINAL SEAT
		DATE 1/30/71	BY 101

			
<p>NOTES:</p> <ol style="list-style-type: none"> 1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE. 2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN. 		<p>MODELLER VIEWER</p>	<p>PRIME COMPUTER, INC. NATICK, MASS</p>
<p>CHO TOL .01 FILE EDGES OFF / / /</p>		<p>DATE 7/30/68</p>	<p>DESIGNED BY RON RENKE DRAWN BY C CHECKED BY F SEAL NO. 17301</p>

												
<p>NOTES:</p> <ol style="list-style-type: none"> 1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE. 2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN. 		<table border="1"> <tr> <td data-bbox="1308 904 1362 1315">MODELLER</td> <td data-bbox="1362 904 1509 1315">VIEWER</td> <td data-bbox="1308 266 1362 904" rowspan="2">PRIME COMPUTER, INC. NATICK, MASS</td> </tr> <tr> <td data-bbox="1362 904 1509 1315"> CID 101.01 TILE EDGES OFF , , , </td> <td data-bbox="1362 266 1509 904"> <table border="1"> <tr> <td data-bbox="1362 691 1445 904">RON RENKE</td> <td data-bbox="1445 691 1509 904">C</td> </tr> <tr> <td data-bbox="1362 478 1445 691">DND 101</td> <td data-bbox="1445 478 1509 691">F (NAL. SEAT 3</td> </tr> </table> </td> </tr> </table>		MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS	CID 101.01 TILE EDGES OFF , , ,	<table border="1"> <tr> <td data-bbox="1362 691 1445 904">RON RENKE</td> <td data-bbox="1445 691 1509 904">C</td> </tr> <tr> <td data-bbox="1362 478 1445 691">DND 101</td> <td data-bbox="1445 478 1509 691">F (NAL. SEAT 3</td> </tr> </table>	RON RENKE	C	DND 101	F (NAL. SEAT 3
MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS										
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RON RENKE	C											
DND 101	F (NAL. SEAT 3											



NOTES:

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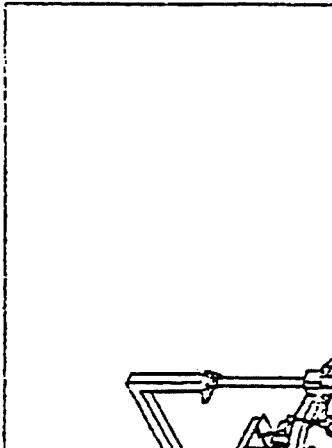
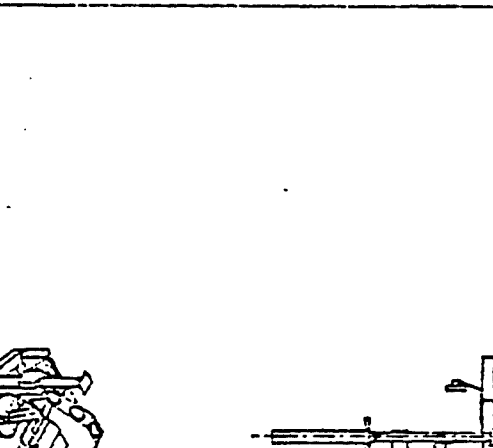
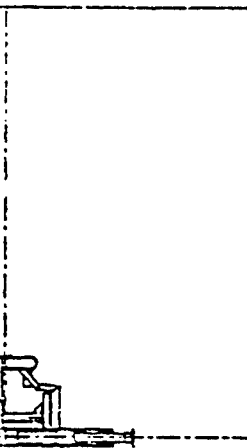
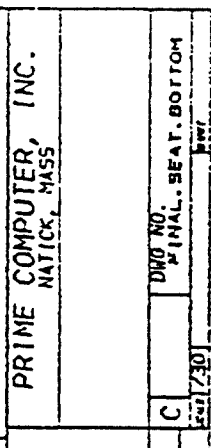
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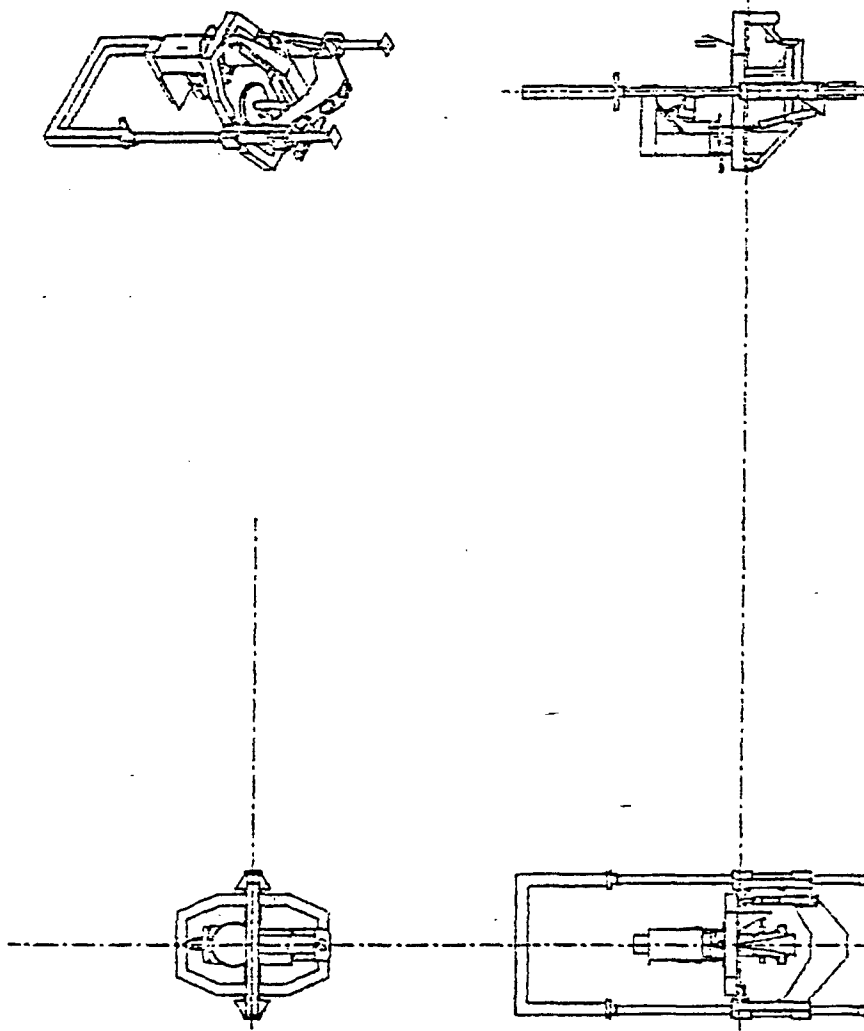
CHD TOL .01
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PRIME COMPUTER, INC.
NATICK, MASS

RON RENKE

DRG NO. 1-1
F-1 (NAL. SEAT 4)

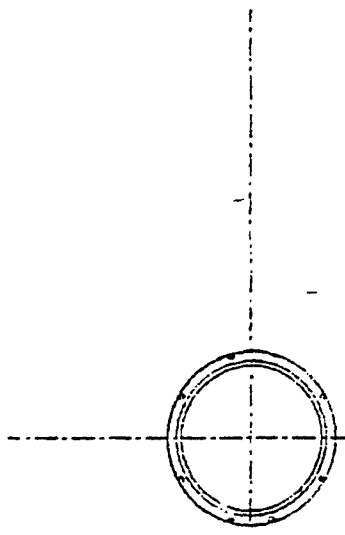

			
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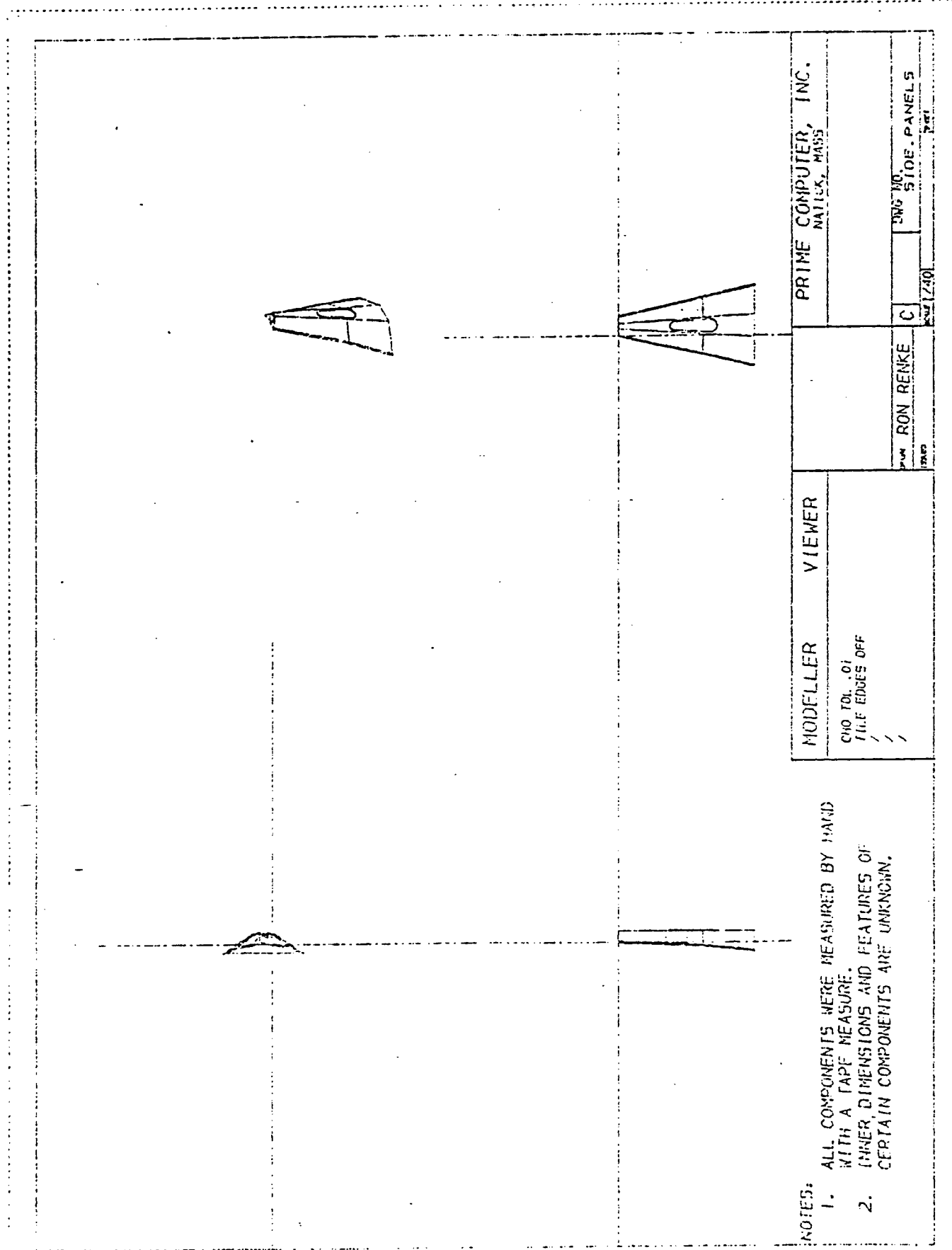


NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
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MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS	
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	RON RENKE		

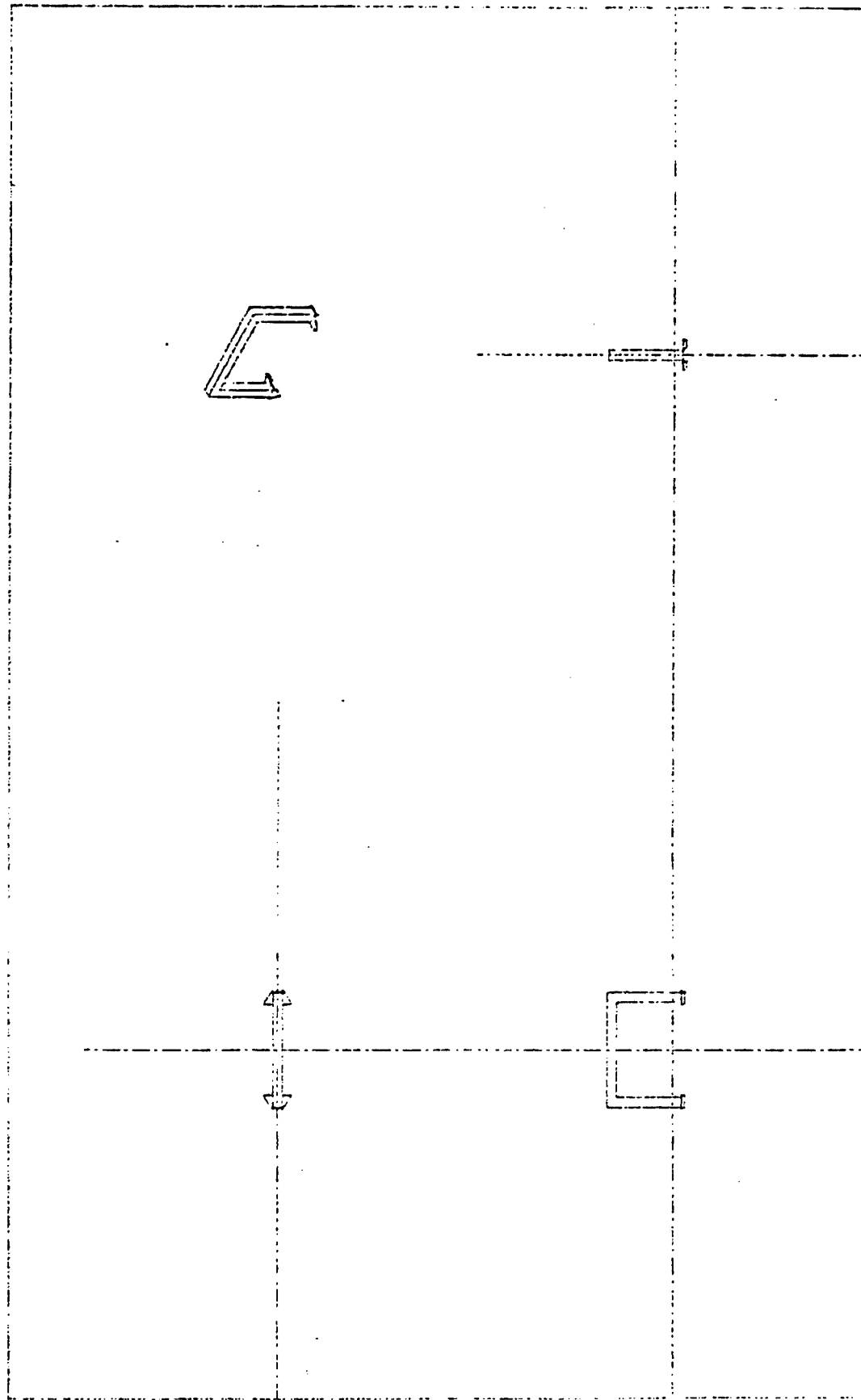
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MODELLER	VIEWER													
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DATE	DRAWN													
BY	C													
DATE	1/30													
BY	YAW, RING													



MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS	
CHO TOL .01 FILE EDGES OFF / / /		DESIGNED BY RON RENKE	DWG NO. SIDE PANELS 12401

NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.



NOTES.

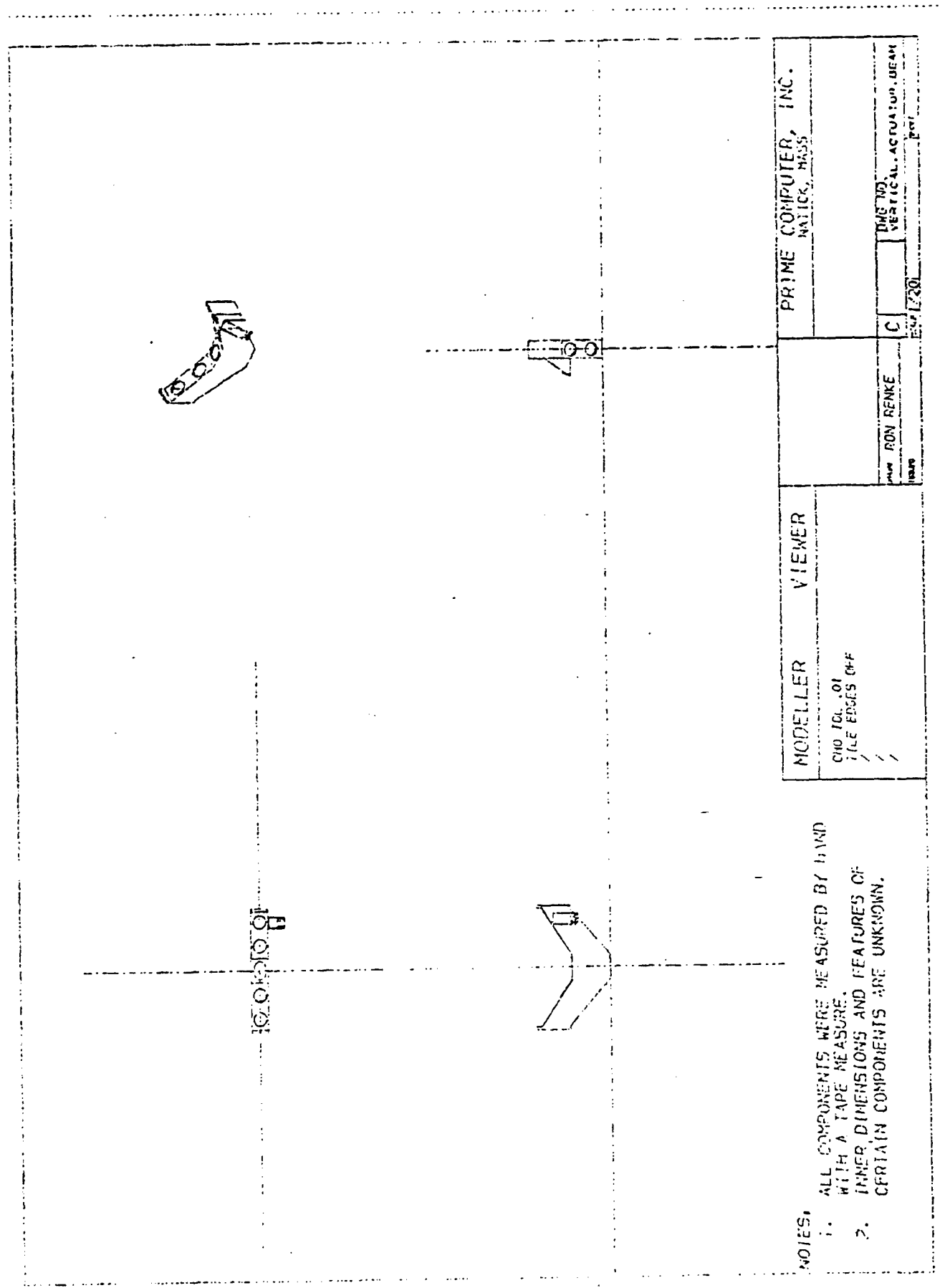
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2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS
CHD TOL .01 TILE EDGES OFF / /	RON RENKE DATE 12/30/71	C TOP BEAM DATE 12/30/71

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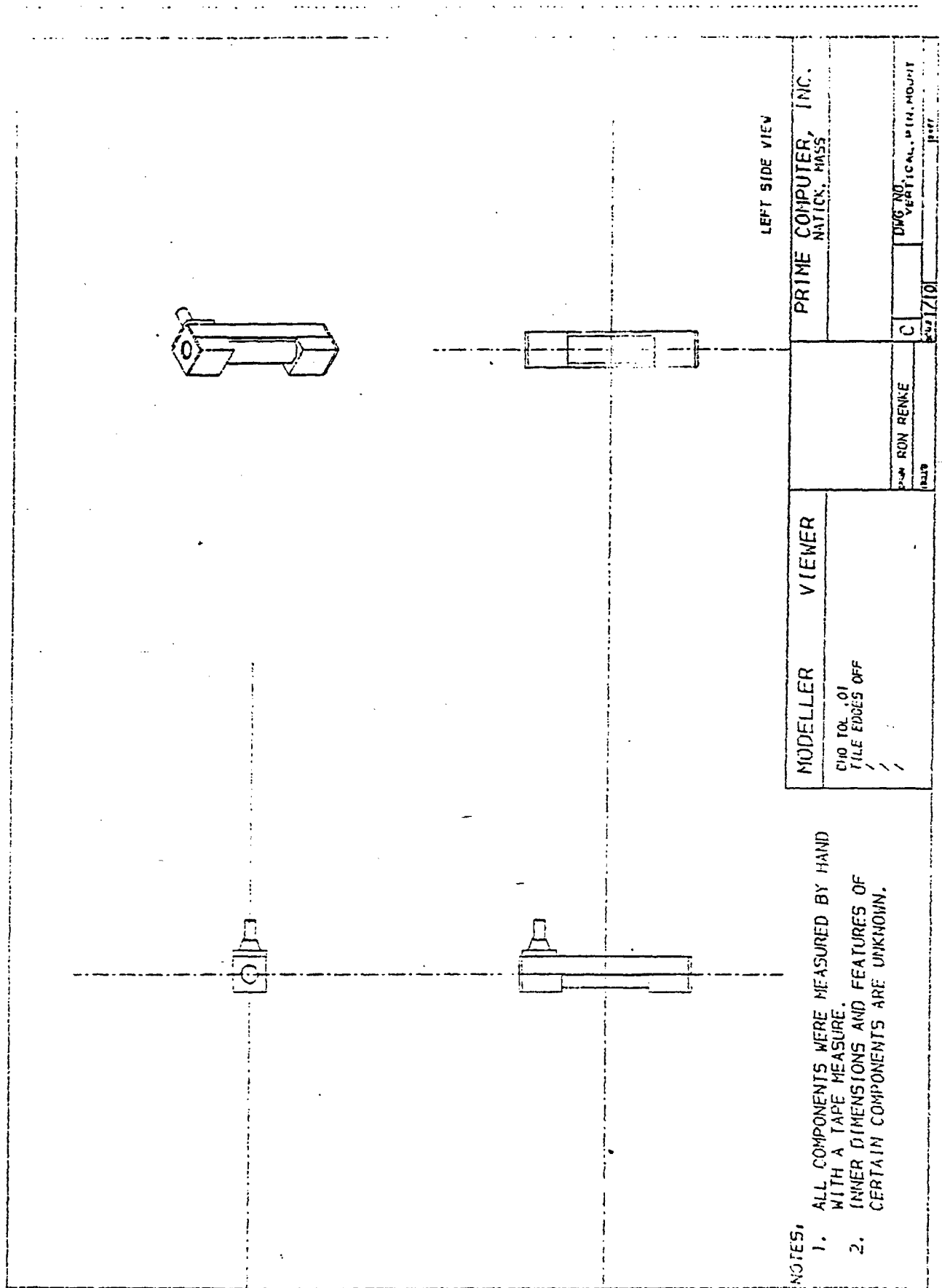
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1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.



- NOTES:
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 2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

MODELLER	VIEWER	PRIME COMPUTER, INC.
CHD JCL .01 FILE EDGES OFF /		NATICK, MASS
/		
/		
/		
	RON RENKE	DATE NO.
	C	VERTICAL ACTUATOR, BEAM
		REV 1220



NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

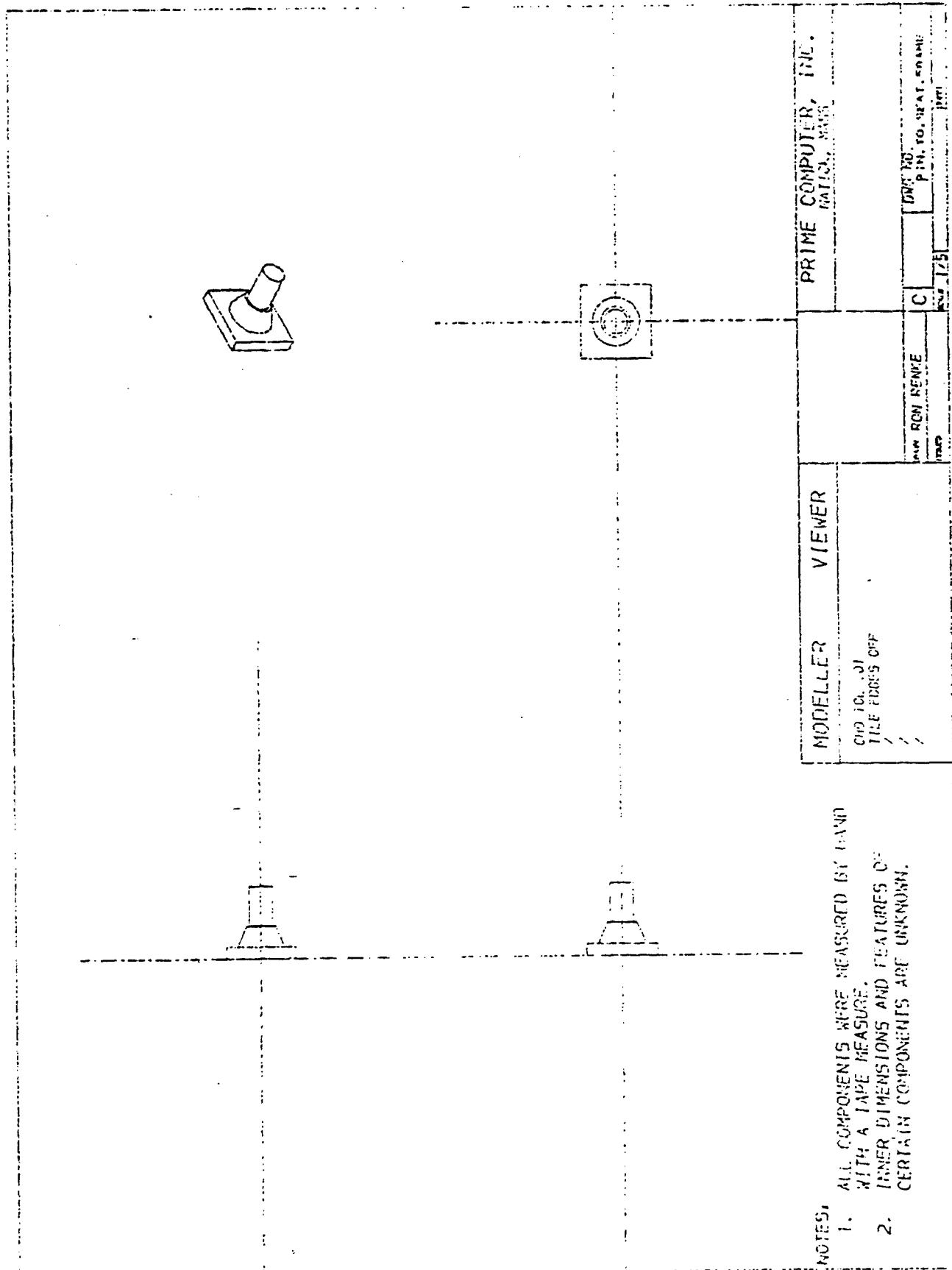
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C10 TOL .01
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PRIME COMPUTER, INC.
NATICK, MASS.

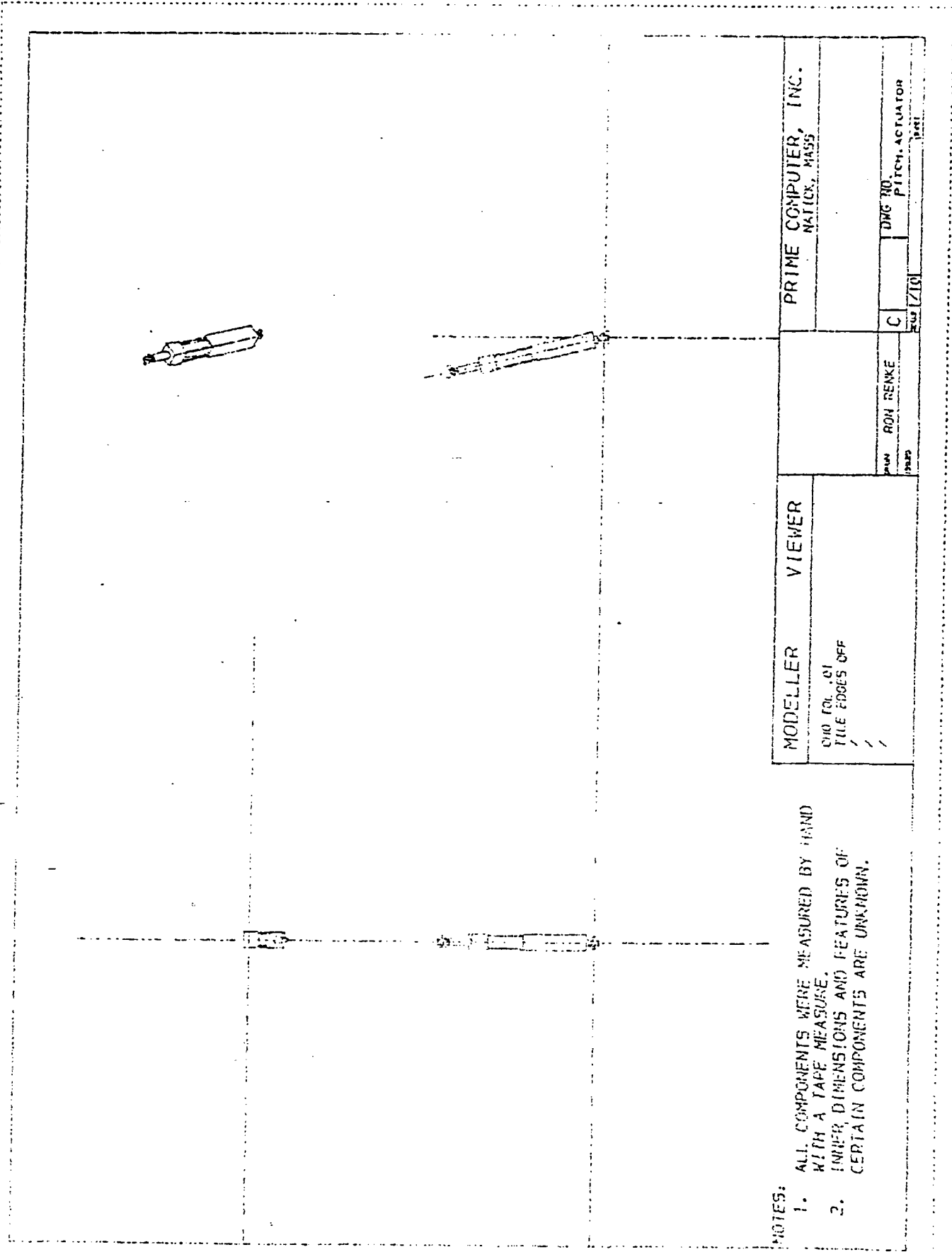
DATE 1/10
DRAWN RON RENKE
DWG NO. 1000
VERTICAL PTH. MOUNT

LEFT SIDE VIEW



- NOTES:
1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
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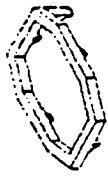
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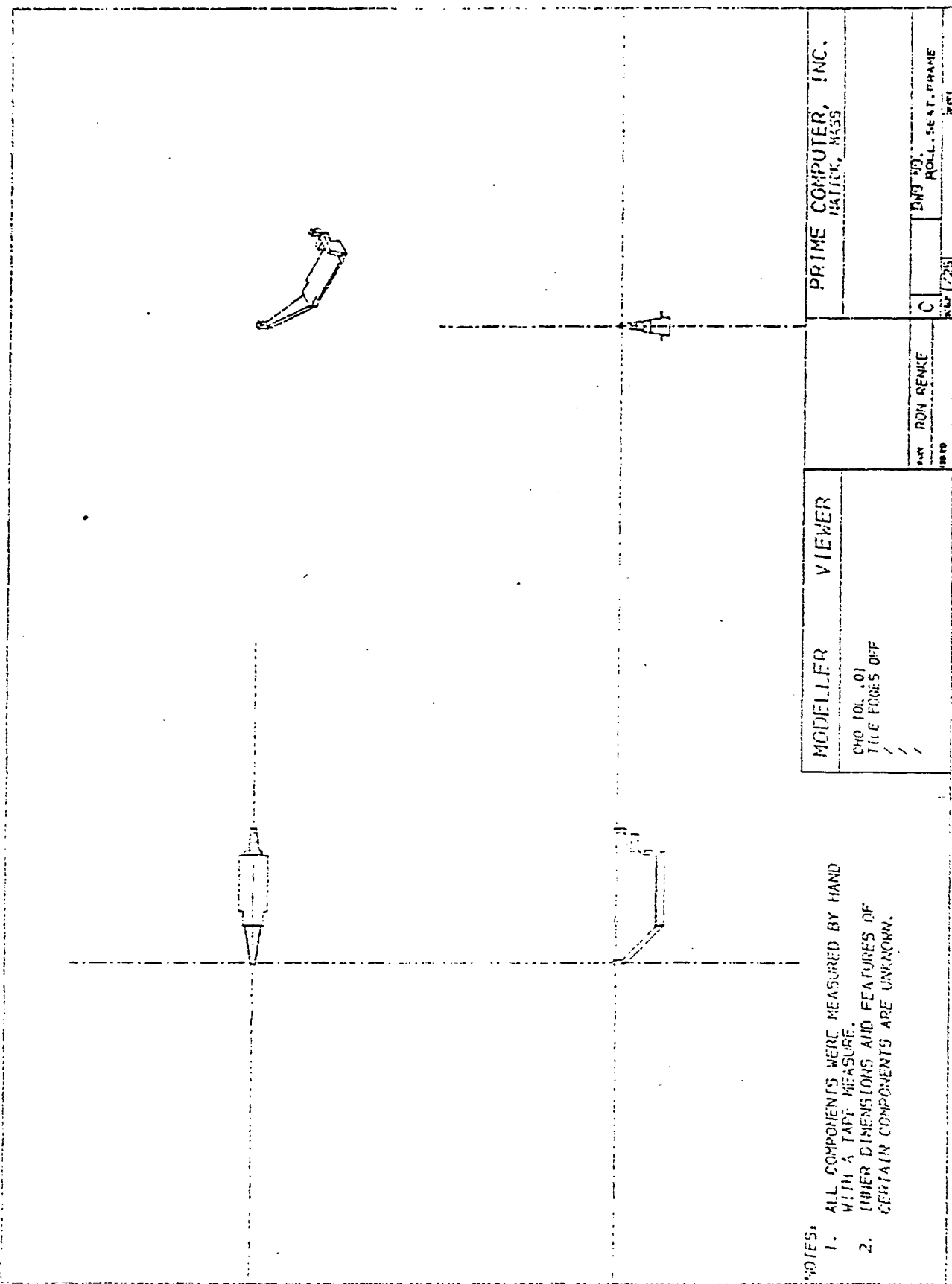


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		DWG NO	PITCH ACTUATOR
		REV	1/10

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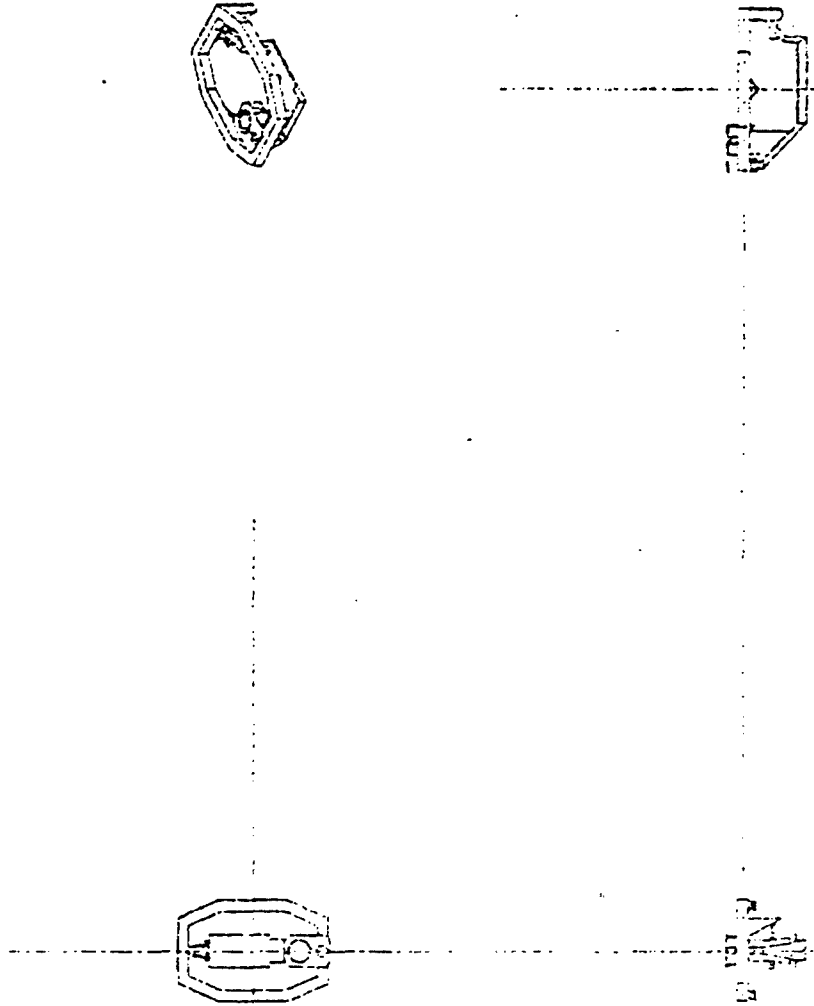
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2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

		<p>NOTES:</p> <ol style="list-style-type: none"> 1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE. 2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.
<p>MODEL</p>	<p>VIEWER</p>	<p>PRIME COMPUTER, INC. NATICK, MASS</p>
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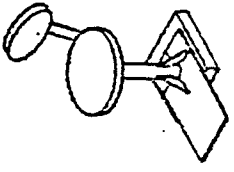
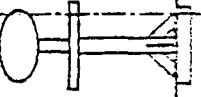
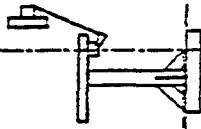
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2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.



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MODELLER	VIEWER	PRIME COMPUTER, INC. NATICK, MASS
CUD 101-01 TILE EDGES OFF / /	CON RENKE	DWG NO. SEAT, FRAME, W/ROLL
		DATE 1/2/01

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MODELLER CID TOL .01 TITLE EDGES OFF / / /	VIEWER	PRIME COMPUTER, INC. NATICK, MASS										
RON RENKE 10/17/75		C										
SEAT		10/17/75										

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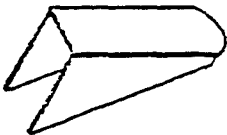
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2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

24-24

NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
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				ROLL ACTUATOR	
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		PRIME COMPUTER, INC.	
		NATICK, MASS	
MODELLER CHO TOL .01 TILE EDGES OFF / / /	VIEWER	RUM RUM RENKE C	DDC 710 ROLL ACTUATOR BRACKET 1/23

NOTES:

1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
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- NOTES:
1. ALL COMPONENTS WERE MEASURED BY HAND WITH A TAPE MEASURE.
 2. INNER DIMENSIONS AND FEATURES OF CERTAIN COMPONENTS ARE UNKNOWN.

MODELLER VIEWER

CHG TO: CJ
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PRIME COMPUTER, INC.
BATTLE, MASS




RON BENKE

C

PRIME COMPUTER, INC.

REV 1221

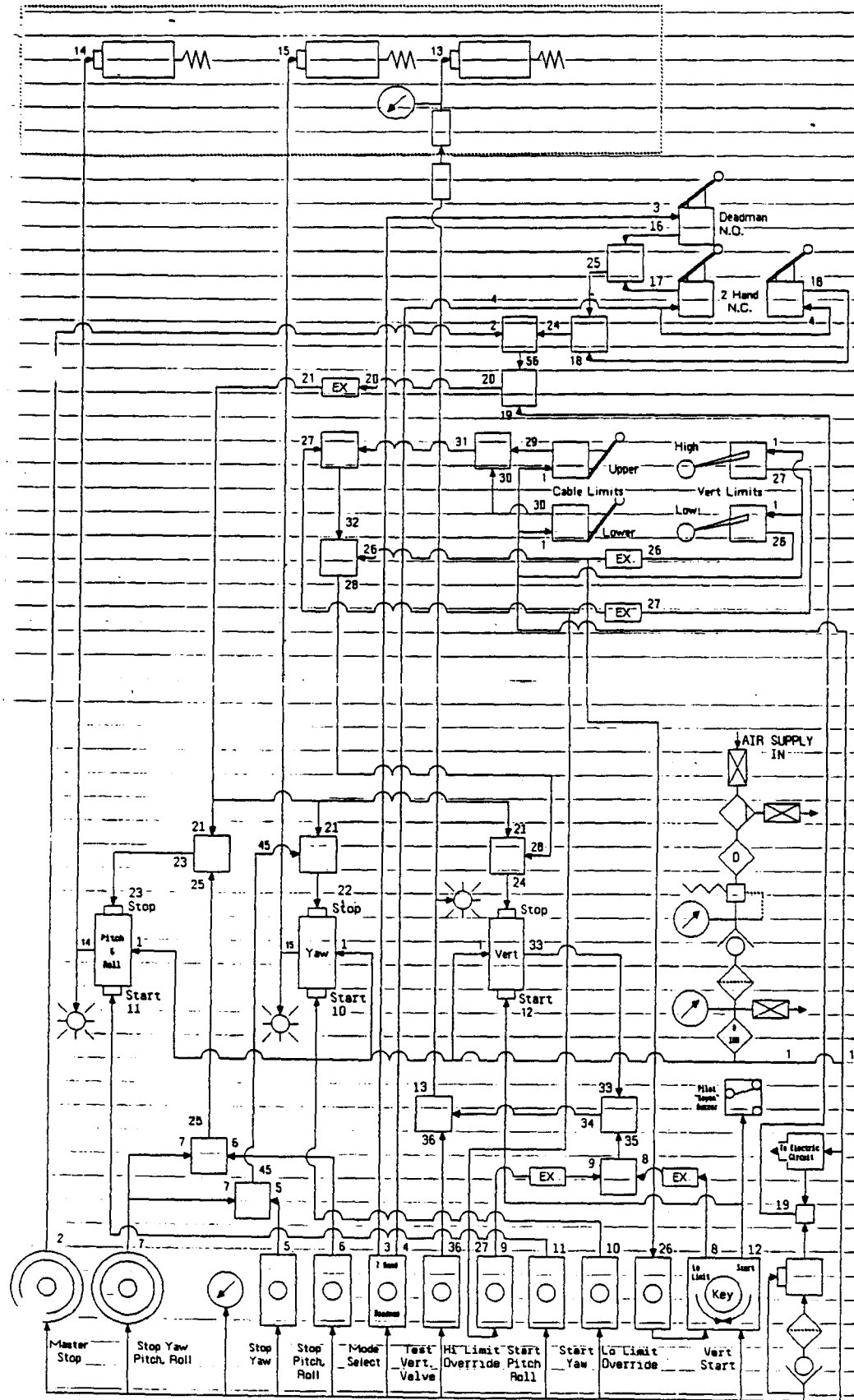
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		NATICK, MASS	
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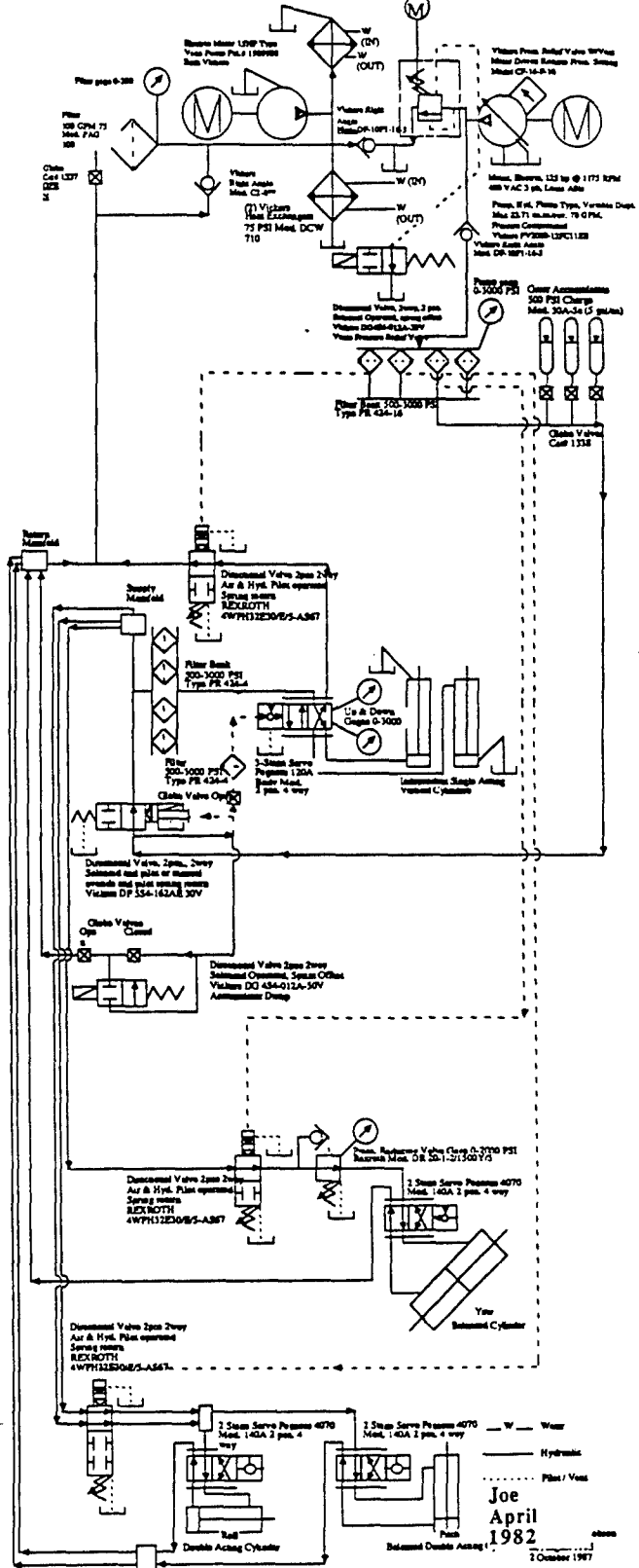
APPENDIX B

RIDE MOTION SIMULATOR PNEUMATIC SAFETY AND CONTROL SCHEMATIC

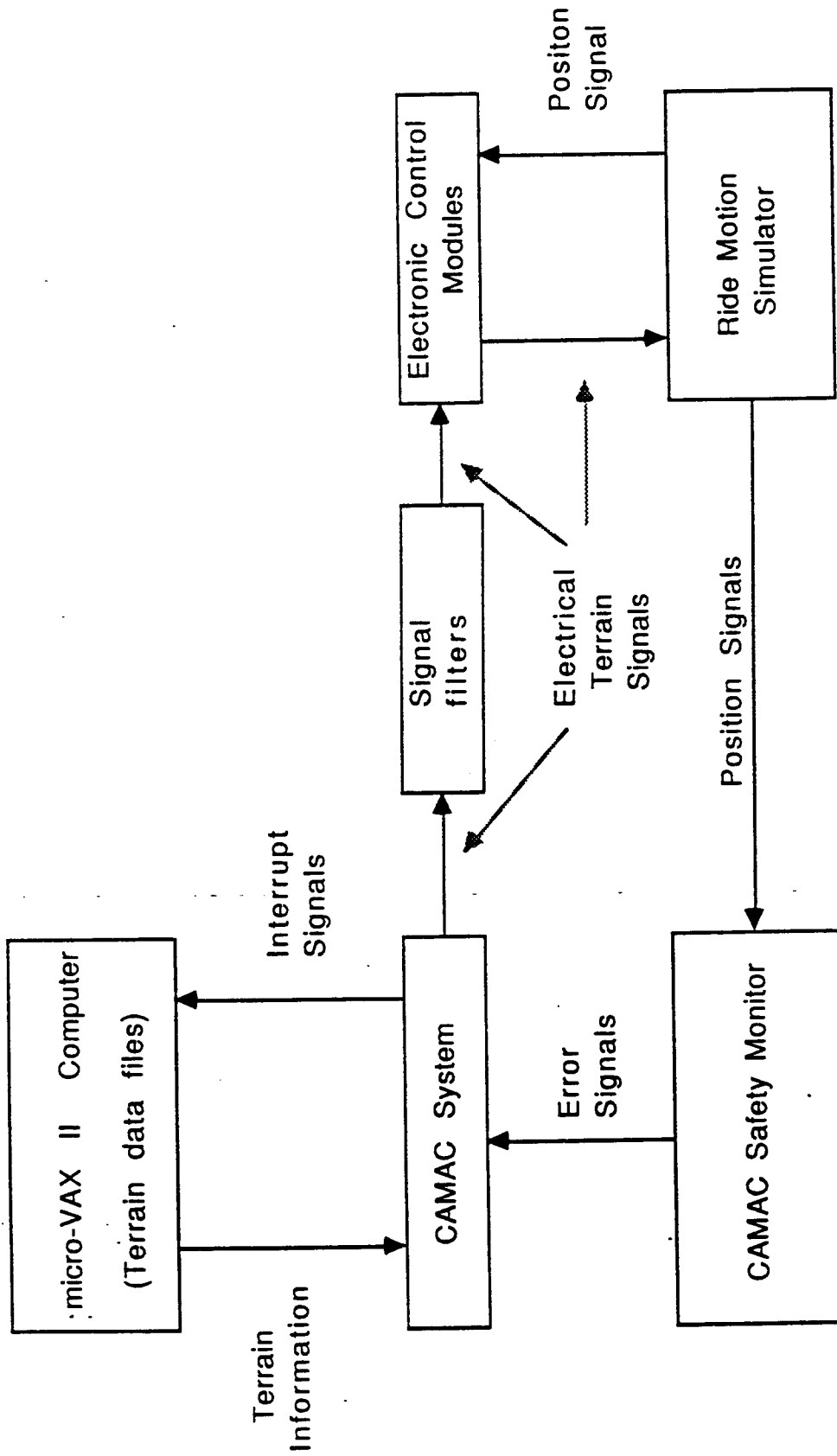
HYDRAULIC VALVES



RIDE MOTION SIMULATOR HYDRAULIC SCHEMATIC DIAGRAM



APPENDIX C



Signal Control Block Diagram

APPENDIX D

FREQ RESP
20.0

dB

-60.0

1 Log Hz

VERTICAL CLOSED LOOP

100

D-3

FREQ RESP
180

Phase

Deg

-180

1 Log Hz

VERTICAL CLOSED LOOP

100

D-3

FREQ RESP
20.0

dB

-60.0

1 Log Hz

ROLL CLOSED LOOP

100

D-4

FREQ RESP
180

Phase

Deg

-180

1 Log Hz

ROLL CLOSED LOOP

100

FREQ RESP
20.0

dB

-60.0

1 Log Hz

PITCH CLOSED LOOP

100

D-5

FREQ RESP
180

Phase

Deg

-180

1 Log Hz

PITCH CLOSED LOOP

100

D-5

FREQ RESP
20.0

dB

-60.0

1 LOG HZ

YAW CLOSED LOOP

100

D-6

9-D

FREQ RESP
180

Phase

Deg

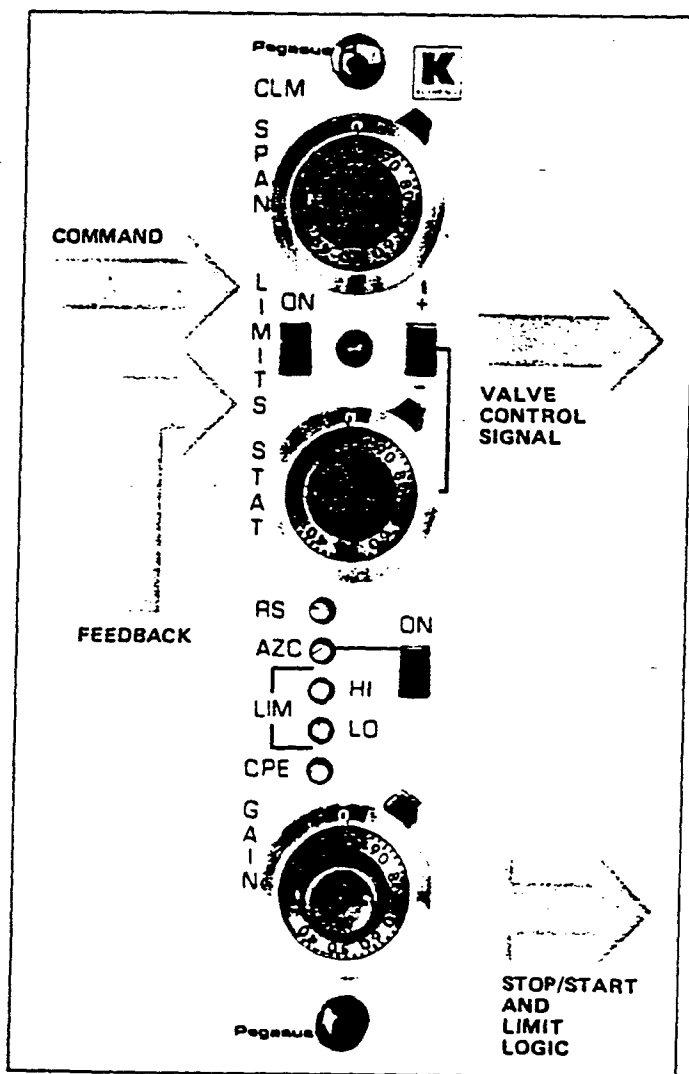
-180

1 LOG HZ

YAW CLOSED LOOP

100

APPENDIX E



- Limit detector with independently adjustable high and low thresholds
- 4-position limit monitor selector
- Mechanical limit switch monitor logic
- Override mode provides indication of limit condition with no logic output from module
- Buffered meter output isolates critical signals in the servo loop
- Remote controlled loop gain responds to changes in transducer conditioner gain switch

DESCRIPTION

The Control Loop Module (CLM) is the forward loop signal processing section of the 5100 Series Control System, providing the circuitry to accept and compensate inputs, generate a servo amplifier drive signal, and detect limits. When combined with the Transducer Conditioner, Analog Meter and Servo Amplifier Modules, the CLM provides a flexible controller adaptable to any hydraulic or pneumatic control application.

The CLM, with its easily accessible controls, internal power regulation and compact modular design, offers solutions to common servo control problems.

CONTROL LOOP MODULE FUNCTION

INPUT CIRCUITRY

A command signal of up to 20 volts peak-to-peak, from a function generator, computer, magnetic tape, or other source is input to the differential amplifier and attenuated by the buffer isolated span potentiometer. This dynamic command signal can be amplitude modulated to zero span by programmable logic responding to cycle start and limit logic inputs. The resulting signal is summed with the bias level controlled by the static potentiometer and polarity switch.

ERROR AND CONTROL CIRCUITRY

The Feedback signal input to the CLM is subtracted from the composite Command signal. The difference is the Error signal. This Error signal is input to the control compensation circuitry of the CLM which generates a Modified Error signal to drive the servo amplifier or Inner Loop Module. This Modified Error signal is the sum of several inputs: Amplified Error, Differentiated Error or Rate Stabilization, Integrated Error or Automatic Zero Control, Differentiated Command or Command Pre-Emphasis, and two inputs which can be any form of feedback or cross coupling.

FEATURES

- Differential input results in low common mode noise
- Amplitude modulated command senses cycle control logic and gently increases the command level, protecting delicate specimens
- Rate stabilization for accuracy at high frequencies
- Command pre-emphasis provides extended high frequency response with no degradation in system stability
- Automatic Zero Control (AZC) circuitry provides extremely accurate control through error integration

PERIPHERAL FUNCTIONS WITHIN THE CLM

As the CLM accepts command and feedback inputs and generates a modified error output, non-servo loop functions are performed. A window comparator monitors Error, Compensated Error, Feedback, or an auxiliary signal to determine if the chosen signal is within independently pre-settable upper and lower limits.

Compensated Error is a signal generated within the CLM that represents deviations of the actual error from normal operating conditions. Phase differences that normally occur at higher frequencies under closed loop conditions, generate error signals of substantial amplitude, preventing "tight" setting of the error limits. Compensated Error compensates for this phase shift at high frequencies, resulting in a signal that indicates only abnormalities in the system to allow setting the error limits to a minimum value.

Additional logic monitors the condition of a remote limit switch. Under normal operation, either limit condition activates the front panel LED and logic outputs from the CLM. In override operation, the window comparator affects only the LED. The limit switch is overridden only during the first ten seconds after the override switch is activated.

CLM CONTROLS AND INDICATORS

COMMAND CONTROL

SPAN

A 10-turn counting dial to accurately control and display the attenuation applied to the signal at the input BNC on the rear panel.

STATIC

A 10-turn counting dial to accurately control and display the absolute value of the applied static bias voltage. For example: "5" corresponds to 5 volts, "10" to 10 volts.

STATIC +/-

A 2-position slide switch to set the polarity of the static bias voltage.

COMPENSATION CONTROL

RS

A 25-turn, screwdriver-adjustable trim pot (potentiometer) to manipulate the high frequency components of the error signal for extended servo loop frequency response.

CPE

A 25-turn trimpot to add high frequency command components to the servovalve drive signal for extended servo loop frequency response without degradation of loop stability.

AZC

A 25-turn trimpot to optimize the rate at which the system null shifts are corrected.

AZC

A slide switch to override the AZC feature.

GAIN

A 10-turn counting dial to set the overall loop gain for optimal loop performance under varying applications.

LIMIT DETECTION CONTROL

LIM(its) HI(gh)/LO(w)

Two 25-turn trimpots to independently set the thresholds of the window comparator.

LIM(its)

A 2-position slide switch to set the limit logic status for normal (on) or override operation.

LIM(its)

A red Light Emitting Diode (LED) to indicate the condition of the internal logic output from the CLM in normal operation, and the condition of the logic in override operation.

CLM REAR PANEL

INPUT

A BNC used to apply differential commands from a function generator or other signal generating device. This connector is not referenced to the 5100 Series rack enclosure, thereby eliminating concern for ground loops and 60 Hz noise.

OUTPUT

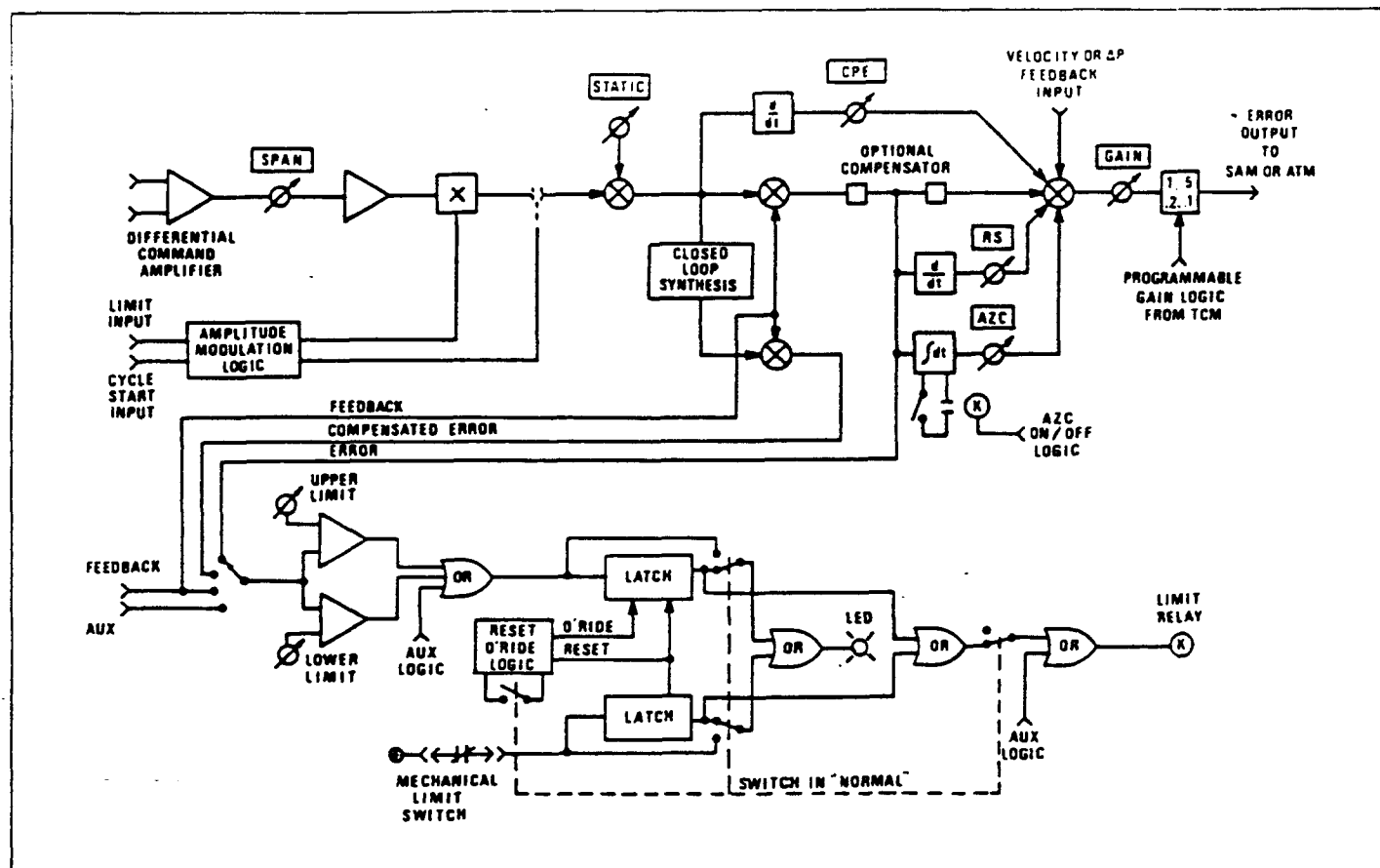
A BNC used to monitor the feedback signal used in the CLM. The signal is buffered, eliminating interference with the closed loop system.

CLM AVAILABLE OPTIONS

REMOTE SPAN AND STATIC CONTROLS allow master control of dynamic command and static bias on all channels of a multi-channel system.

AMPLITUDE MODULATION controls the amplitude of the dynamic command in response to an externally applied signal. Can be used to uniformly program amplitudes in a multi-channel system.

In multi-channel systems, when interaction occurs between channels, CROSS COUPLING INPUTS can be used to null out the interaction.



PARAMETRIC COMPENSATION allows independent adjustment of compensation parameters for use in systems with unusual mechanical characteristics.

ADDITIONAL 5100 SERIES MODULES SUGGESTED FOR CLOSED LOOP CONTROL

TCM TRANSDUCER CONDITIONER MODULE

For AC or DC transducers.

AMM ANALOG METER MODULE

Monitors up to 12 critical signals around the control loop for up to 3-channel systems.

SAM SERVO AMPLIFIER MODULE

Provides control current to virtually any type servo valve.

OPTIONAL EXPANSION MODULES

LDM LIMIT DETECTOR MODULE

Detects over- or under-peak conditions.

FGM FUNCTION GENERATOR MODULE

Sine, square, and triangle waveforms: 0.1 Hz to 1100 Hz.

ATM AMPLIFIER AND TRANSFER MODULE

Accepts error signals from three Control Loop Modules and switches between them electronically for "bumpless" transfer. In addition, it provides control current to virtually any type servovalve.

ILM INNER LOOP MODULE

Feedback conditioner and control for 3-stage servovalves.

CCM CYCLE COUNTER MODULE

Counts cycles of feedback or dynamic command, includes logic to interact with system.

CM CONTROL MODULE

Central control of dynamic command, hydraulics and pump.

SSM SERVO SYSTEM MODULE

A complete servo controller in one module. Contains Command, Static, Error, Compensation, Valve driver, limit detection, transducer conditioner and signal monitoring circuitry in a package 5" x 2-1/4" x 10". (12.7cm x 5.72cm x 25.4cm)

SPECIFICATIONS

Error Detector Adjustment 0 to 100%
External Command Input Level +/- 10V Nominal — +/- 12.5V Maximum
Command Input Impedance 100K balanced
Command Common Mode Rejection Ratio 66dB min. at 60 Hz
Span Control Linearity +/- 0.25% Optional +/- 0.15%
Static Linearity +/- 0.25% Optional +/- 0.15%
Slow Start Adjustment 1 millisecond to 5 seconds
Size 5" x 1.12" x 10" (12.7cm x 2.84cm x 25.4cm)

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servovalves / electronic servo controllers / fatigue-rated actuators / contract testing

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Transducer Conditioner Modules

TCM-1, 2 DESCRIPTION

The Transducer Conditioner Module (TCM) is used in the 5100 Series of modular control electronics for feedback and monitoring applications. The TCM is a complete DC conditioner with a highly stable, differential, instrumentation amplifier providing rejection of hum. Many types of DC transducers can be used with the TCM such as load cells and strain gages.

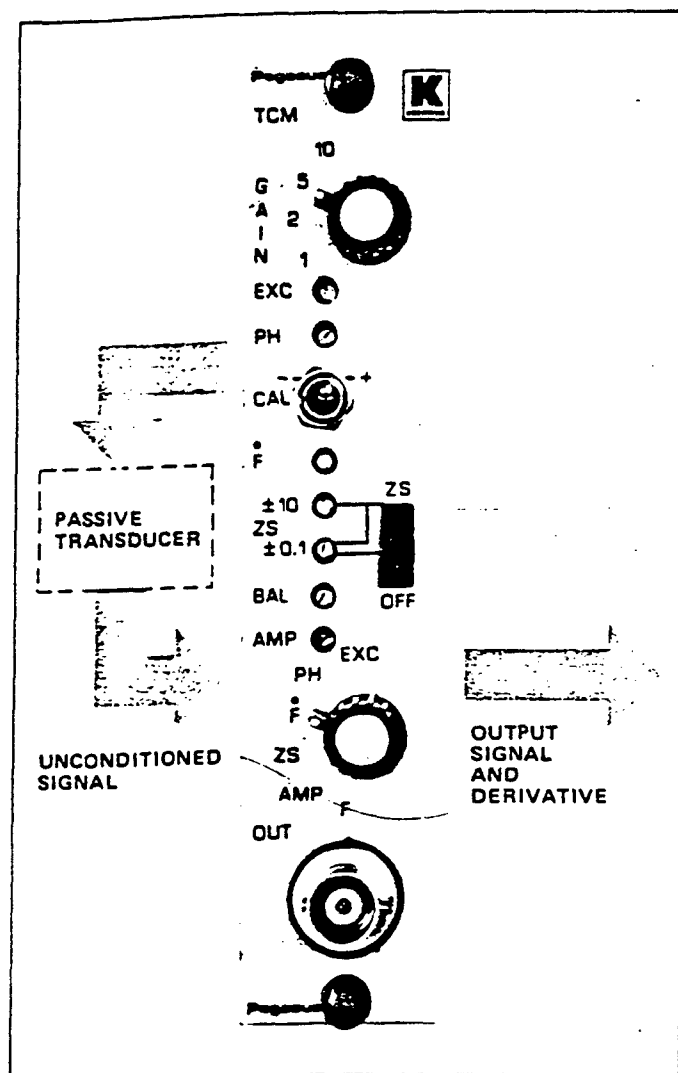
TCM-1, 2 FUNCTION

DC excitation is regulated internally and adjusted by the EXC(itation) pot(entiometer). This signal is input to the output driver which supplies the transducer. A balance signal for resistive bridges is derived from the excitation. The transducer output and balance signal are input to a high quality instrumentation amplifier, the gain of which is selectable by changing a plug-in header. Precise balancing of the amplifier is accomplished by the front panel AMP(lifier) pot. The amplifier output is bandpass filtered and the result is a voltage proportional to the transducer signal. At this point, non-linearities in the transducer can be compensated for by the linearization circuitry. From the linearized signal, zero suppression is subtracted. Zero Suppression (ZS) can be switched to one of three states: Off; "0.1", fine adjustment; and "10 + 0.1", coarse plus fine adjustment.

The resulting signal (Feedback minus ZS), is fine trimmed both in gain and balance, and in the TCM-2, is selectively amplified by either 1, 2, 5, or 10 to generate the final output. Each of the three additional gain ranges in the TCM-2 has an independent calibration and balance adjustment.

Five important signals are supplied to the OUTPUT selector switch. They are: EXC(itation), F-dot (derivative of feedback), ZS (Zero Suppression), AMP(lifier output balance), and F(eedback). The PH(ase) position is not used in the TCM-1 or -2. The selected signal is buffered and output to the BNC connector.

The CAL(ibrate) switch supplies logic to the Automatic Calibration Option Board controlling the application of shunt calibration resistors for bridge transducers. Logic inputs to this board can also be from a peripheral device. Calibration can be inhibited by a Control Module or other logic using the Calibration Enable input.



TCM-1 AND -2 FEATURES

- Signal conditioning gains from 1 to 10,000 (1 to 1000 on the TCM-1)
- Coarse and fine adjustment of Zero Suppression with 3-position mode switch
- Bridge balance adjustment
- Six-position monitor selector switch
- Four gain ranges in multiples of 1, 2, 5, and 10 (not on the TCM-1), switchable from the front panel
- Shunt calibration switch interlocked with system logic (optional)
- Linearity adjustment for asymmetrical transducers
- Derivative output for velocity monitoring and feedback compensation

CONTROLS AND INDICATORS

GAIN (not available in the TCM-1.)

A 4-position rotary switch that selects the amplification of the output signal to 1, 2, 5, or 10. Reduces loop gain proportionally when the TCM is used with the Control Loop Module. This also effects the scaling of the derivative output.

EXC(itation)

A 25-turn, screwdriver-adjustable trim pot(entiometer) that provides accurate calibration of the transducer scaling.

PH(ase)

Not applicable to the TCM-1 or -2.

+/- CAL (with AUTO CAL option only)

A 3-position toggle switch that activates the logic to the calibration board located in the rear section of the TCM.

F(F-dot)

25-turn trim pot that adjusts the gain of the derivative output.

ZS-0.1

A 25-turn trim pot that generates a voltage that is summed with the ZS-10 signal and is variable from plus to minus 10 volts (1% of full scale).

ZS-10

A 25-turn trim pot that generates a DC voltage to be subtracted from the F(eedback) voltage. This voltage can be varied from plus to minus full scale (10 volts).

ZS

A 3-position slide switch that selects which ZS pots are in effect. In 10 and 0.1 position, both pots are in effect and the sum is monitored. In the 0.1 position, only the 0.1 pot is in effect and monitored. In the OFF position, neither switch is effective, but the sum is monitored. Zero Suppression has the same effect on the closed loop as Static bias but the effects are not visible at the output signal of the TCM.

BAL(ance)

25-turn trim pot that is used to null transducer offsets.

AMP

A 25-turn trim pot that adjusts the DC offset of the instrumentation amplifier to zero for any gain used.

OUTPUT

A rotary switch and BNC that provide a monitor for five critical signals at the BNC. These signals are:

- 1) EXC(itation): The total signal to the transducer.
- 2) F dot: The derivative of the output, F.
- 3) ZS: The total ZS subtracted from the F(eedback) signal when ZS is "ON". When ZS is "OFF", this signal is the sum of the two ZS trim pot settings.
- 4) AMP(lifier): The output of the instrumentation amplifier.
- 5) F(eedback): The main output signal of the TCM. PH(ase) is not applicable to the TCM 1 and -2.

REAR PANEL CONTROLS AND INDICATORS

+/- CAL

Three banana jacks that provide for the insertion of a shunt calibration resistor for resistive bridges. The jacks are not supplied if the AUTO CAL option is purchased.

XDCR

An MS-type connector used to interface the TCM to the transducer.

OPTIONS AVAILABLE WITH THE TCM-1 AND -2

AUTO CAL allows the operator to apply shunt calibration resistors to bridge-type transducers from the front panel. It also allows multi-channel systems to be calibrated simultaneously from a remote central location or from a computer command. When the TCM is used with 5100 Series Control Modules, the calibration commands are inhibited when closed loop conditions exist.

The BRIDGE COMPLETION OPTION offers precision, temperature stable resistors to replace up to three sides of a bridge when only one strain gage is to be used as a transducer.

REMOTE RANGING allows remote control of the ranging feature. (Not available on the TCM-1)

ADDITIONAL 5100 SERIES MODULES SUGGESTED FOR CLOSED LOOP CONTROL

CLM CONTROL LOOP MODULE

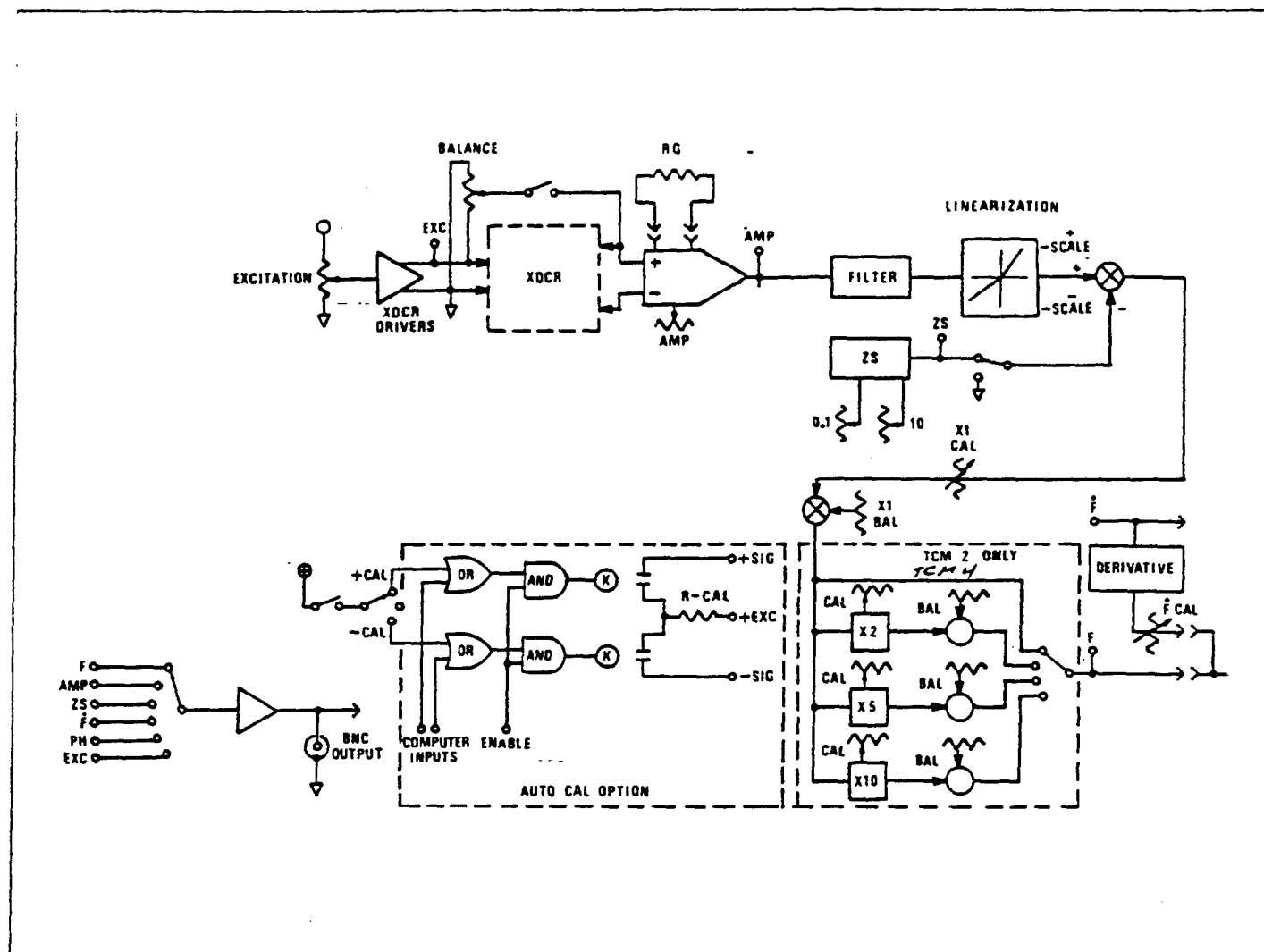
Forward loop signal processing module with limit detection, error compensation and command and static controls.

AMM ANALOG METER MODULE

Monitors up to 12 critical signals around the control loop for up to 3-channel systems.

SAM SERVO AMPLIFIER MODULE

Provides control current to virtually any type servovalve.



OPTIONAL EXPANSION MODULES

LDM LIMIT DETECTOR MODULE

Detects over- or under-peak conditions.

FGM FUNCTION GENERATOR MODULE

Sine, square, and triangle waveforms; 0.1 Hz to 1100 Hz.

ATM AMPLIFIER AND TRANSFER MODULE

Accepts error signals from three Control Loop Modules and switches between them electronically for "bumpless" transfer. The ATM also provides control current to virtually any type servovalve.

ILM INNER LOOP MODULE

Feedback conditioner and control for 3-stage servovalves.

CCM CYCLE COUNTER MODULE

Counts cycles of feedback or dynamic command, includes logic to interact with system.

CM CONTROL MODULES 1, 2, 3, AND 4

Central control of dynamic command, hydraulic and pump.

TCM TRANSDUCER CONDITIONER MODULES 3 AND 4

Complete signal conditioner for DC or AC transducers.

SSM SERVO SYSTEM MODULE

A complete servo controller in one module. Contains command, Static, Error, Compensation, Valve driver, limit detection transducer conditioner and signal monitor circuitry in a package 5" x 2-1/4" x 10", (12.7cm x 5.72cm x 25.4cm).

TCM-1 AND -2 SPECIFICATIONS

EXCITATION SUPPLY

Output Voltage 0 to 10 Volts DC
Maximum Load Current 100 mA
Output Power 1.2 Watts (short circuit protected)
Temperature Drift..... 0.005%/degrees C.

AMPLIFIER

Gain Ranges X1, X2, X5, X10 (TCM-2)
Gain 1 to 100 at X1 max gain — 10,000 at X10 (TCM-2)
Fine Zero Suppression..... +/- 1% of full scale
Coarse Zero Suppression..... +/- 100% of full scale
Time Zero Drift..... .75 micro Volts/24 hours RTI (includes excitation supply drift)
Temp Zero Drift..... +/- 2 micro Volts/ degrees C RTI @ gain 1000
Input Impedance..... 10 meg Ohms
Output Voltage..... +/- 10 Volts full scale
Output Current..... 5 mA maximum
Output Linearity..... +/- 0.1%
Frequency Response..... +/- 1 dB DC to 1000 Hz
Phase Shift <7 degrees @ 100 Hz
Common Mode Rejection 110 dB @ 60 Hz with 350 Ohm imbalance in source impedance
Differentiator Response +/- 2dB to 1000 Hz
Size..... 5" x 1.12" x 10" (12.7cm x 2.84cm x 25.4cm)

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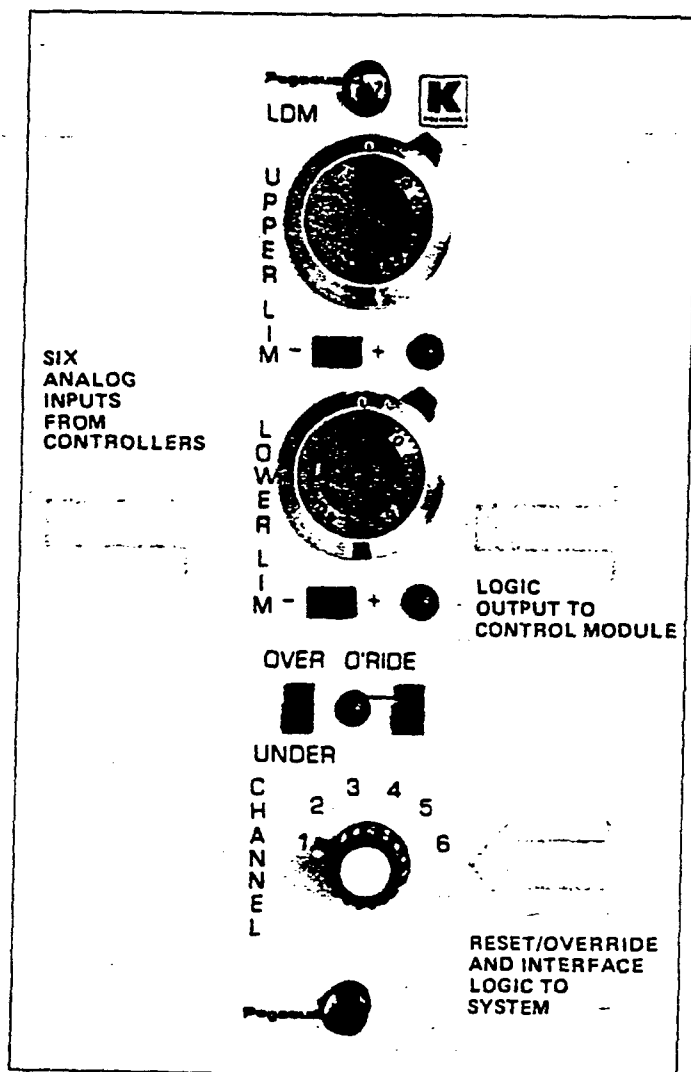
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LDM

Limit Detector Module



FEATURES

- Ten-turn dials and polarity switches to set upper and lower thresholds
- Upper and lower indicators independently show polarity of exceeded limit
- Override switch with flashing indicator
- Switch to select overlimit or underlimit detection
- Six-position input selector switch

DESCRIPTION

The Pegasus Limit Detector Module (LDM) is an extremely versatile component in the 5100 Series of control electronics. It provides a means of detecting

When the peak amplitude varies beyond preset thresholds, system shutdown can be initiated. In multi-channel systems the LDM allows selection of one of six input signals. Shutdown can occur in the entire system or if desired, only in the channel being monitored.

The LDM is designed for use with the Pegasus 5100 Series rack mount or desk top enclosures.

LDM FUNCTION

The LDM accepts six analog signals at the input selector switch. The selected signal is buffered and filtered to reduce high frequency noise components. The resulting signal is compared with three thresholds; the upper and lower limit thresholds which are set by ten-turn locking dials and polarity switches, and the average of these two voltages which is interpreted as a zero-crossing threshold.

In the over-peak mode, the outputs of the upper and lower comparators indicate when the input signal is above the upper threshold or below the lower threshold. This information is latched, drives a red Light Emitting Diode (LED) and is output from the LDM. Figure I illustrates a lower over-peak limit.

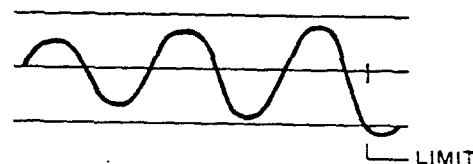


Figure I

In the under-peak mode, under-peak limit detection is not armed until the threshold is achieved at least once. An under limit occurs after any cycle in which the thresholds are not achieved. Figure II illustrates an under-peak limit.

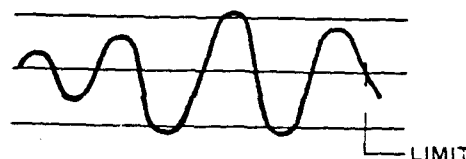


Figure II

In either over-peak or under-peak operation, the override mode disables the logic outputs of the LDM. The limit LED's indicate when over-peak conditions occur. This is the condition that is normally used during set-up. The override mode is signified by a flashing red LED.

With the override switch in the normal or non-override position, logic is output from the LDM when a limit occurs. When the limit condition is cleared, the override switch serves to reset the internal logic.

CONTROLS AND INDICATORS

UPPER LIM(it) (control)

A 10-turn POT(entiometer) with counting dial to set the upper limit threshold from zero to +/- 10 Volts.

LOWER LIM(it) (control)

A 10-turn pot with counting dial to set the lower limit threshold from zero to +/- 10 Volts.

UPPER LIM +/- (control)

A slide switch to control the polarity of the UPPER LIM(it) threshold.

LOWER LIM +/- (control)

A slide switch to control the polarity of the LOWER LIM(it) threshold.

UPPER LIM (indicator)

A red Light Emitting Diode (LED) to indicate that the upper limit has occurred.

LOWER LIM (indicator)

A red LED to indicate that the lower limit has occurred.

OVER/UNDER (control)

A slide switch to control the limit detection mode.

O'RIDE / (normal)

A slide switch to inhibit limit logic signals generated by the LDM.

O'RIDE (indicator)

A red LED to indicate when the LDM is in O(ver)'RIDE. Short flashes indicate override is a result of the LDM override switch. Long flashes indicate a remote source is generating the override condition.

CHANNEL

A 6-position rotary switch to select signal inputs and route logic outputs.

OPTIONS AVAILABLE

REMOTE OVERRIDE-RESET allows a central controller to reset or disable limit detectors in a large system. Remote override results in a change in the duty cycle of the flashing override LED.

A self-contained relay contact that can be output directly to a remote device or signal.

ADDITIONAL 5100 SERIES MODULES AVAILABLE

TCM TRANSDUCER CONDITIONER MODULE

For AC or DC transducers.

AMM ANALOG METER MODULE

Monitors up to 12 critical signals around the control loop for up to 3-channel systems.

SAM SERVO AMPLIFIER MODULE

Provides control current to virtually any type servovalve.

FGM FUNCTION GENERATOR MODULE

Sine, square, and triangle waveforms; 0.1 Hz to 1100 Hz.

ATM AMPLIFIER AND TRANSFER MODULE

Accepts error signals from three Control Loop Modules and switches between them electronically for "bumpless" transfer. Also provides control current for virtually any type of servovalve.

CCM CYCLE COUNTER MODULE

Counts cycles of feedback or command, includes logic to interact with system.

CM CONTROL MODULES 1, 2, 3, AND 4

Central control of dynamic command, hydraulics and pump.

CLM CONTROL LOOP MODULE

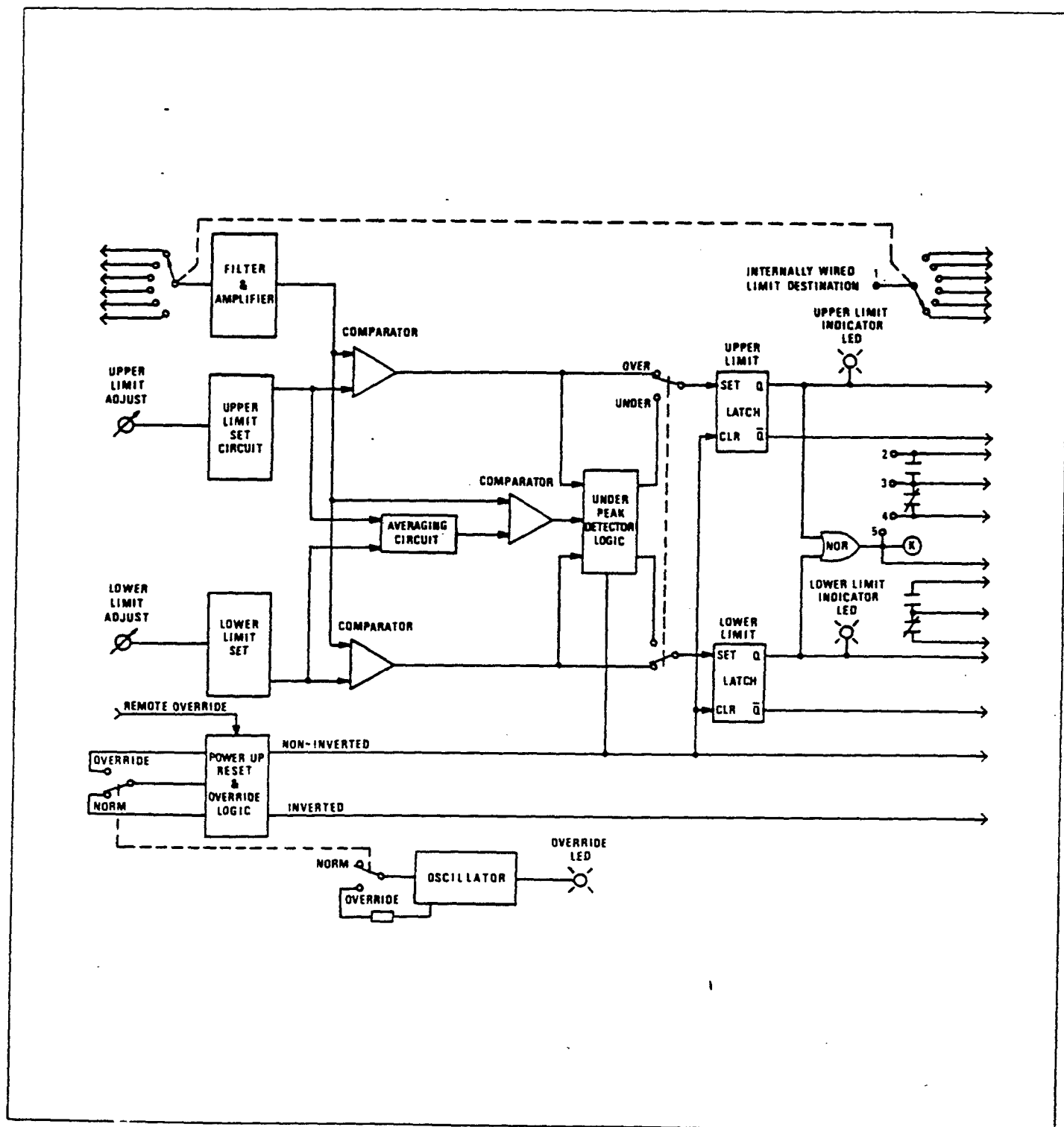
Forward loop signal processing module with limit detection, error compensation, and command and static controls.

SSM SERVO SYSTEM MODULE

A complete servo controller in one module. Contains Command, Static, Error, Compensation, Valve driver, limit detection, transducer conditioner and signal monitoring circuitry in a package 5" x 2-1/4" x 10", (12.7cm x 5.72cm x 25.4cm).

ILM INNER LOOP MODULE

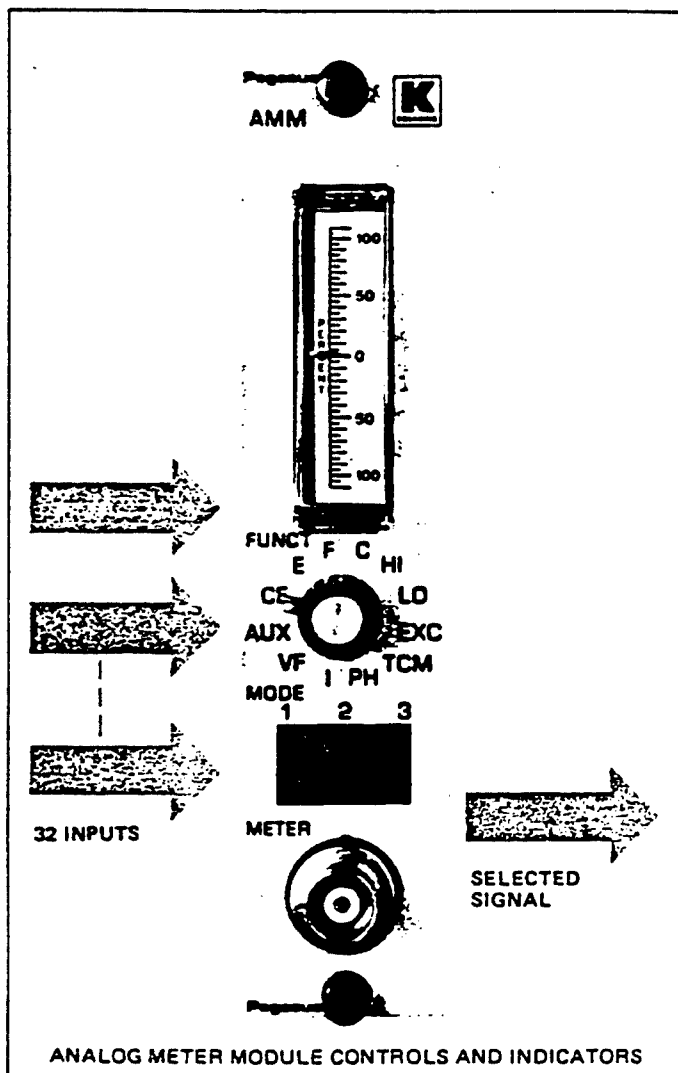
Feedback conditioner and control for 3-stage servovalves.



SPECIFICATIONS

Number of inputs6
Input Range+/- 10 Volts full scale
Input Impedance100K Ohms
Frequency RangeDC to 1 KHz
Threshold Potentiometer Linearity0.25% (.15% available)
Detection Repeatability+/- .05% of Range
Size5" x 1.12" x 10" (12.7cm x 2.84cm x 25.4cm)

Analog Meter Module



FEATURES

- 12 signals that can be monitored in any of three channels
- Buffered output that protects critical signals such as Error, Feedback, and Command
- Analog meter that provides accurate self-contained display
- Compact design that is compatible with Pegasus 5100 Series Enclosures

DESCRIPTION

In the 5100 Series of servo control electronics, the Analog Meter Module (AMM) provides a single point where all critical signals can be displayed and monitored. The display is an accurate, compact,

edge-reading, analog meter. When higher resolution or permanent records are required, the BNC interfaces the AMM to a digital volt meter, oscilloscope or strip chart recorder.

AMM FUNCTION

Inputs to the AMM from the Control Loop Module include:

Compensated Error	CE
Error	E
Feedback	F
Command	C
High Limit Threshold	HI
Low Limit Threshold	LO

Inputs to the AMM from the Transducer Conditioner Module are:

Excitation	EXC
Selector Switch Output	TCM
Phase	PH

The Inner Loop Module supplies valve position or feedback, VF, and the Amplifier and Transfer Module or Servo Amplifier Module supplies the valve current, I. Three auxiliary signals can also be monitored. These signals are selected by the rotary FUNCT(ion) switch and the 3-position MODE switch. The selected signal is buffered by an accurate, high-speed operational amplifier to ensure isolation and to eliminate any distortion when monitoring high frequency signals at the BNC output. The output of this amplifier is distributed to both the Analog Meter and the BNC.

CONTROLS AND INDICATORS

FUNCT(ion)

A 12-position rotary switch which selects one of twelve signals within a given channel (mode). Two of the twelve positions are common to all three channels (valve feedback and valve current).

MODE

A 3-position rocker switch which selects one of the three channels to be monitored. With the FUNCT(ion) switch in the valve feedback or valve current positions, the MODE switch has no effect.

ANALOG METER

An indicator that provides a visual display of the analog signal selected by the FUNCT(ion) and MODE switches. The range of the meter is ± 10 volts, indicated as $\pm 100\%$.

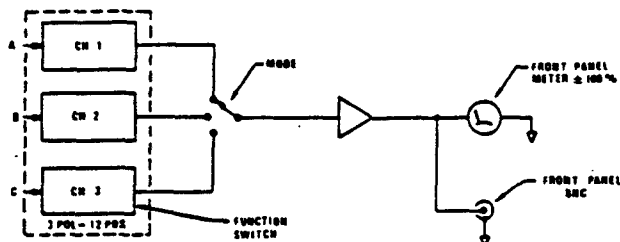
METER

A BNC-type connector which provides a buffered output of the analog signal selected.

REAR PANEL

METER OUT

A BNC-type connector providing the same signal as the front panel METER BNC.



5100 SERIES EXPANSION MODULES

CLM CONTROL LOOP MODULE

Forward loop signal processing module with limit detection, error compensation and command and static controls.

TCM TRANSDUCER CONDITIONER MODULE

For DC or AC transducers.

SAM SERVO AMPLIFIER MODULE

Provides control current to virtually any type servovalve.

SPECIFICATIONS

Total Number of Monitor Points	32
Input Impedance	1Meg Ohm
Frequency Response	Flat DC to 15 KHz
Gain	1 +/- .001
Output	+/- 10 volts into 2K Ohms
Linearity	+/- 0.01%
Drift3 Microvolts/°C
Size	5" x 1.12" x 10" (12.7cm x 2.84cm x 25.4cm)

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Represented By:

LDM LIMIT DETECTOR MODULE

Detects over- or under-peak conditions.

FGM FUNCTION GENERATOR MODULE

Sine, square, and triangle waveforms; 0.1 Hz to 1100 Hz.

ATM AMPLIFIER AND TRANSFER MODULE

Accepts error signals from three Control Loop Modules and switches between them electronically for "bumpless" transfer. The ATM also provides control current to virtually any type servovalve.

CCM CYCLE COUNTER MODULE

Counts cycles of feedback or dynamic command, includes logic to interact with system.

CM CONTROL MODULE

Central control of dynamic command, hydraulics and pump.

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Feedback conditioner and control for 3-stage servovalves.

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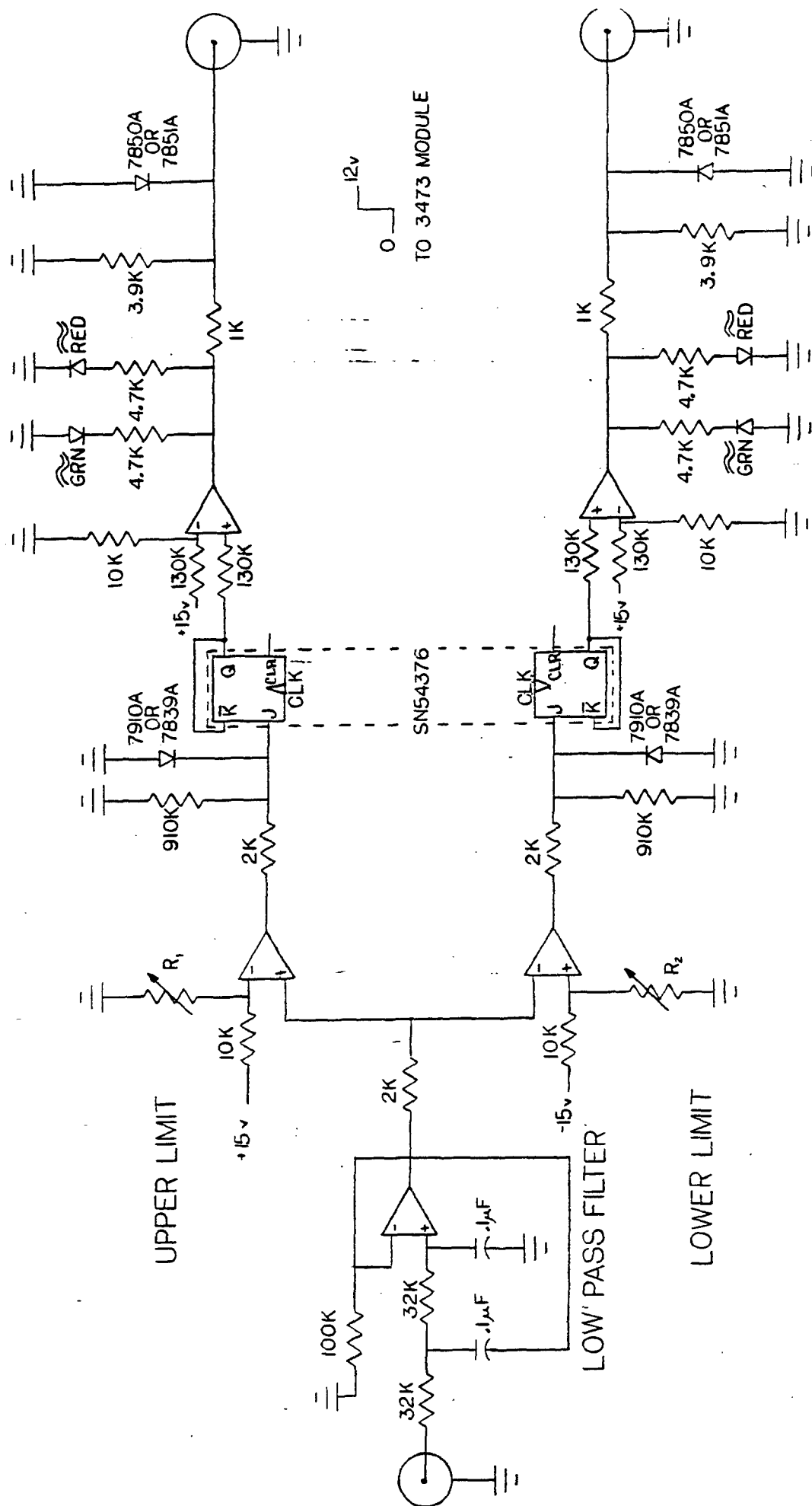
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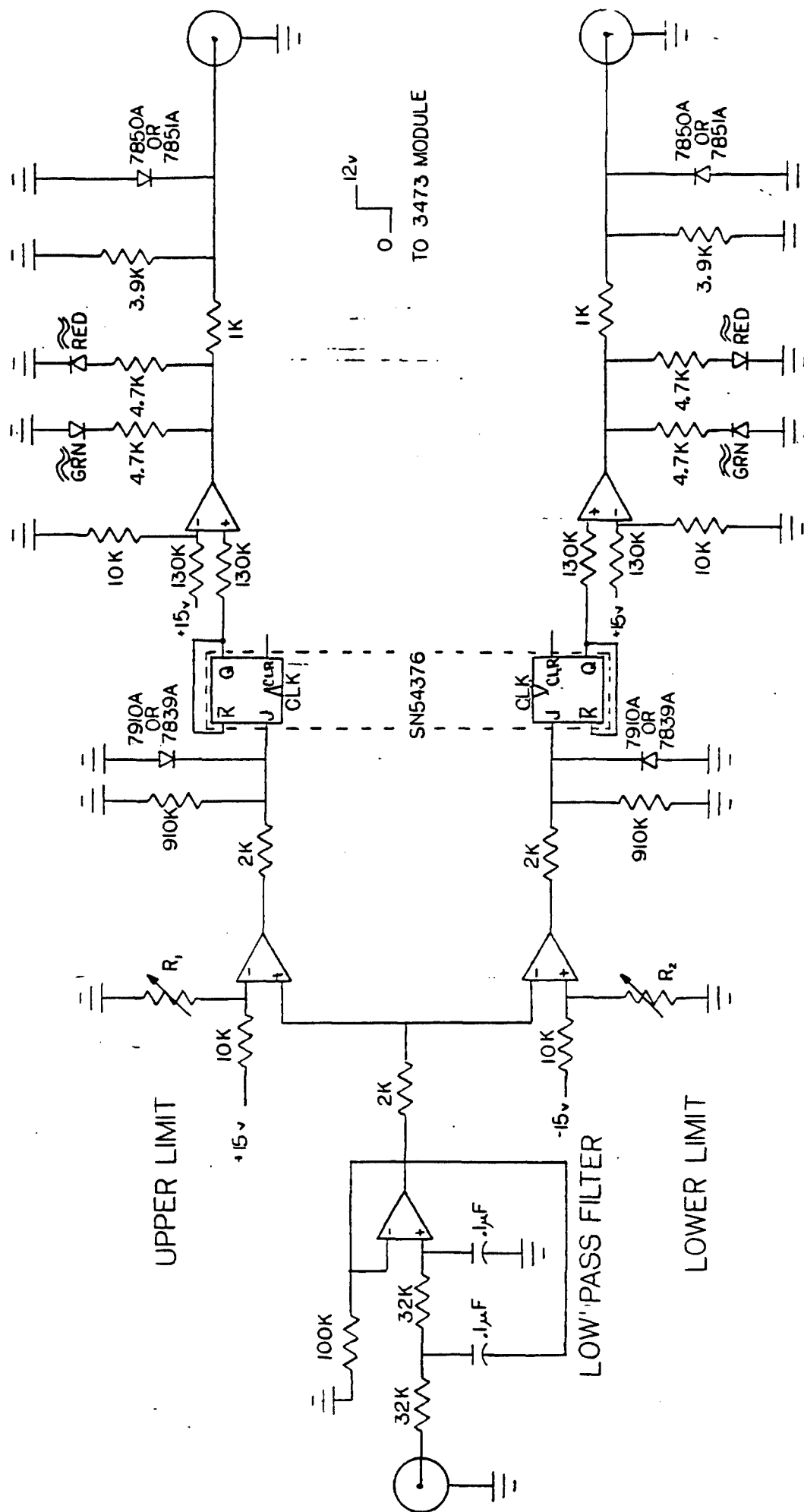
APPENDIX F



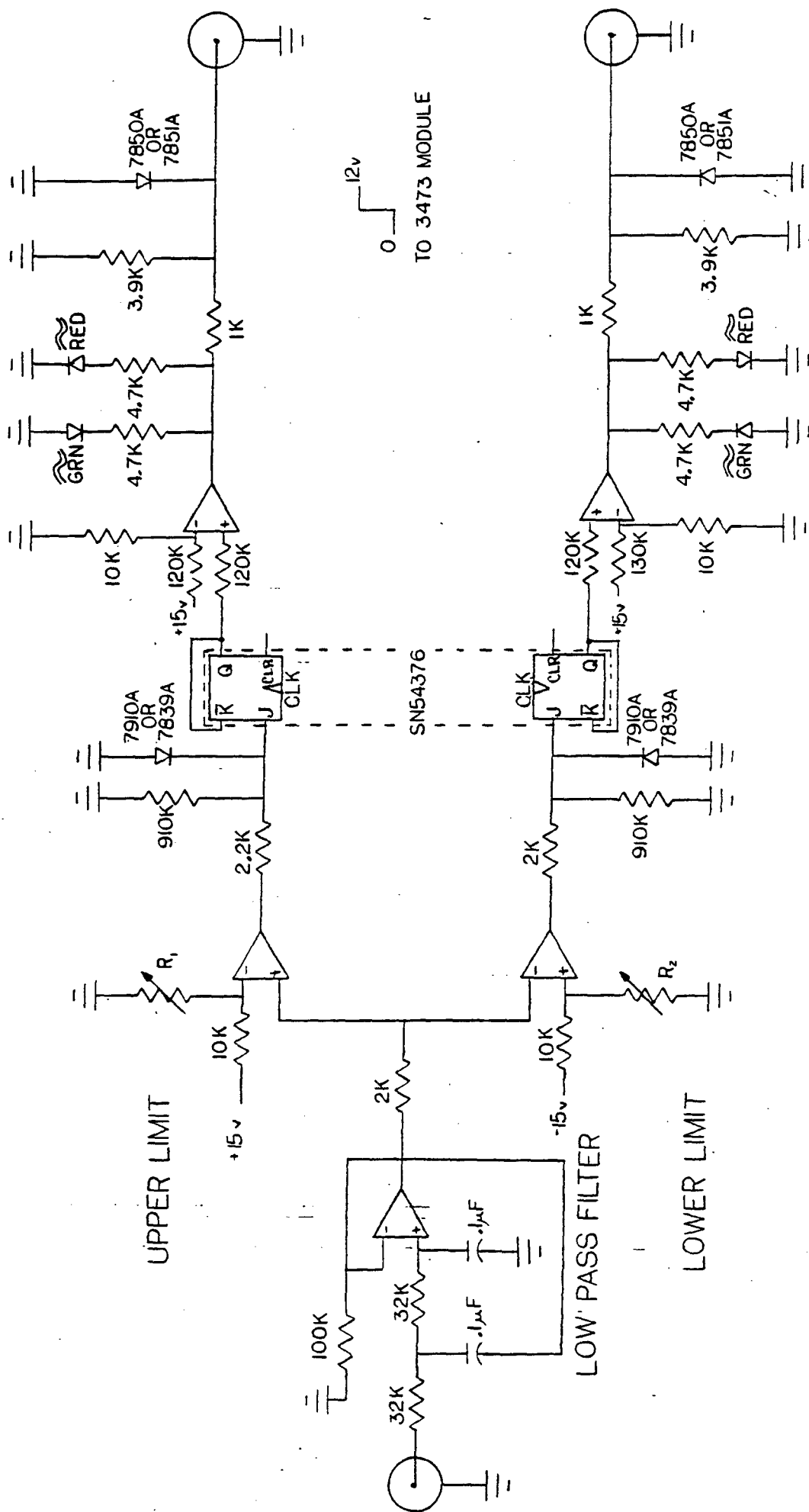
RIDE MOTION SIMULATOR COMPARATOR CIRCUIT VERTICAL



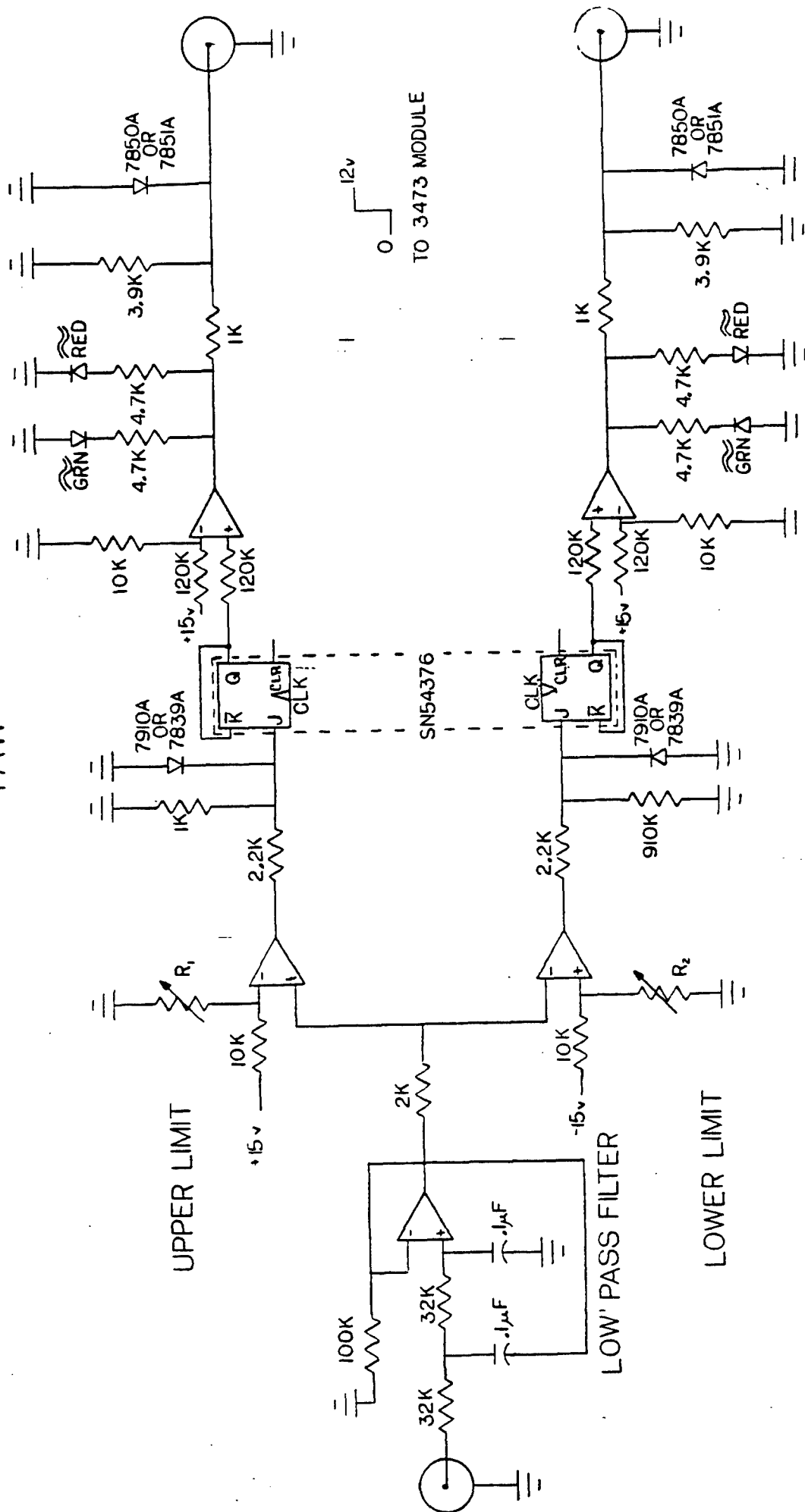
RIDE MOTION SIMULATOR COMPARATOR CIRCUIT ROLL



RIDE MOTION SIMULATOR COMPARATOR CIRCUIT PITCH



RIDE MOTION SIMULATOR COMPARATOR CIRCUIT YAW



F-6

FINAL DESIGN : 30 OCT 1987

A. REID

G. HUDAS

APPENDIX G



CAMAC SAFETY CONNECTIONS

CAMAC SAFETY MONITOR BOX

Emergency Shutdown	(Immediate)	----->
Slow Shutdown	(Ramp-down)	----->
Vertical Upper Limit	(Immediate)	----->
Vertical Lower Limit	(Immediate)	----->
Roll Upper Limit	(Immediate)	----->
Roll Lower Limit	(Immediate)	----->
Pitch Upper Limit	(Immediate)	----->
Pitch Lower Limit	(Immediate)	----->
Yaw Upper Limit	(Immediate)	----->
Yaw Lower Limit	(Immediate)	----->

CAMAC BACKPANEL CONNECTIONS

Input Pin #1
Input Pin #11
Input Pin #3
Input Pin #4
Input Pin #5
Input Pin #6
Input Pin #7
Input Pin #8
Input Pin #9
Input Pin #10



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